NOAA. NMFS TM.SEFSC 383

NOAA TECHNICAL MEMORANDUM
NMFS-SEFSC-383

DOCUMENT
LIBRARY
Woods Hole Oceanographic
Institution

Movements, Site Fidelity, and Respiration Patterns of Bottlenose Dolphins on the Central Texas Coast

By

Bernd Würsig and Spencer K. Lynn

U.S. Department of Commerce
National Oceanographic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149

QL
737
.C432
W8
1996

June 1996

NOAA TECHNICAL MEMORANDUM
NMFS-SEFSC-383

Movements, Site Fidelity, and Respiration Patterns of Bottlenose Dolphins on the Central Texas Coast

By

Bernd Würsig and Spencer K. Lynn

U.S. DEPARTMENT OF COMMERCE
Mickey Cantor, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
D. James Baker, Administrator

NATIONAL MARINE FISHERIES SERVICE
Rolland A. Schmitten, Assistant Administrator for Fisheries

June 1996

This Technical Memorandum series is used for documentation and timely communication of preliminary results, interim reports, or similar special-purpose information. Although the memoranda are not subject to complete formal review, editorial control, or detailed editing, they are expected to reflect sound professional work.

NOTICE

The National Marine Fisheries Service (NMFS) does not approve, recommend, or endorse any proprietary product or material mentioned in this publication. No reference shall be made to NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends, or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose or intent to cause directly or indirectly the advertised product to be used or purchased because of NMFS publication.

This report should be cited as follows: Würsig, B. and S. K. Lynn. 1996. Movements, site fidelity, and respiration patterns of bottlenose dolphins on the central Texas coast. NOAA Tech. Mem. NMFS-SEFSC-383, 111 pp.

Authors' affiliations: Texas A&M University, Marine Mammal Research Program, 4700 Avenue U, Bldg. 303, Galveston, TX 77551.

Copies may be obtained by writing the Southeast Fisheries Science Center, the primary author, or:

National Technical Information Service
5258 Port Royal Road
Springfield, VA 22161
Telephone: (703) 487-4650
FAX: (703) 321-8547
Rush Orders: (800) 336-4300

This is Southeast Fisheries Science Center Contribution MIA-95/96-40.

Movements, Site Fidelity, and Respiration Patterns of Bottlenose Dolphins on the Central Texas Coast: A Report to the National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida

By

Bernd Würsig and Spencer K. Lynn

Texas A&M University
Marine Mammal Research Program
4700 Ave. U, Bldg. 303
Galveston, TX 77551

ABSTRACT

Radio-tracking of 10 bottlenose dolphins (*Tursiops truncatus*), from 9 July 1992 to 13 September 1992, and photographic surveys of 35 freeze-branded dolphins, from May 1992 to June 1993, were conducted in the Matagorda Bay area of Texas, in response to a mass mortality event which occurred between Matagorda and Aransas Bays, Texas, during spring 1992. The primary goals of the study were to assess range size and site fidelity, as well as to initiate a long-term ecological study by collecting data on social and behavioral patterns.

The Matagorda Bay dolphin population was found to be numerically robust, occupying all regions of the bay surveyed. Mean range size, based on radio telemetry, was 140 km^2 (SD = 90.7, n = 10 dolphins). Males and females had similar range sizes though males visited the extremities of their ranges more frequently or for longer periods. Several generalities were observed: (1) Dolphins were capable of, and often did, traverse their range in several hours. (2) Dolphins traveled widely on some days, perhaps crossing their own ranges, while on other days movement was very confined, within 1–2 km^2. This did not appear to have a temporal or geographic pattern. (3) Dolphins tended to spend about 1–4 days in a particular portion of their range. (4) Movement tended to be more confined at night than during daytime. (5) Dolphins tended to visit the extremes of their ranges only in the daytime. The assertions of (4) and (5) may be biased as a result of less sampling effort at night, with fewer triangulations than during daytime and no visual sightings.

Most, if not all, of the 35 freeze-branded dolphins appeared to be resident to the Matagorda–Espiritu Santo Bay area with much fluidity of group membership. Overall mark/recapture population size estimates from photo-identification suggested that 218 ± 71.4 (95% CI) dolphins utilized an area of 312 km² in Matagorda and Espiritu Santo Bays, similar to an estimate made in 1981. Dolphins spent longer times at the surface and dove less often at night, indicating lower activity levels at night. Observations of long-distance movement between Texas bays, and an autumn increase in dolphin numbers in the study area, suggested that the study animals were not an isolated population.

ACKNOWLEDGMENTS

Radio-tracking 10 dolphins simultaneously and for 24 hr/day is quite an undertaking, and we had outstanding and very dedicated assistance in the field from Windi Allman, Stacie Arms, Angela Beaty, R. A. Blaylock, R. H. Defran, Lisa delos Santos, Kellie Fashe, Dagmar Fertl, Anna Forest, Claire Graham, Adam Grundt, Cara Gubbins, Mike Jackson, D'ann Jorgenson, Tom Kiekhefer, Linda Price-May, Kim McDaniel, Janet Morrison, Jan Robinson, Andrew Schiro, Steve Schneider, Lisl Shoda, J. Holly Smith, Bill Stevens, Gil Swain, Wang Ding, Wang Qin, David Weller, Brian Wilson, Kim Würsig, and Melany Würsig. Additionally, Angela Beaty, Nathalie Clauss, Morgan Collins, Mark Dhruv, Holly Fortenberry, Janet Morrison, Ashlesha Patel, Tracy Salvi, Meike Scheidat, Andrew Schiro, Sandy Smith, Tamara Svoboda, and David Weller helped with analysis of the over 4,500 photos, and data entry of the over 1,500 bearings and 28,000 min of surfacing intervals. Of course, none of this would have been possible without the help of the National Marine Fisheries Service (NMFS); and the capture, veterinary, and physiology teams. We thank especially Larry Hansen and Gerald Scott of NMFS; Jay Sweeney and Rae Stone of Dolphin Quest and Waikoloa Marine Life Fund; and Graham Worthy and Tamara Miculka of the Texas A&M University Marine Mammal Research Program. Thomas Healy of the U. S. Fish and Wildlife Service, Ted Fuller of the U.S. Coast Guard, and Norman Boyd of the Texas Parks and Wildlife Department were especially helpful with local logistics. Our pilots were Sam Sailor (Piper Cub), Allan Potter of the U.S. Coast Guard Reserve (Cessna 172), and Mike Newcome of GalvAero (Cessna 177).

This work was carried out under NMFS Permit #728 to Würsig and Worthy and SeaGrant Project #R/ES-55. The capture, sampling, and tagging was conducted by the SEFSC under an emergency authorization conferred pursuant to Section 109(h) of the Marine Mammal Protection Act. This report was improved by comments from Alejandro Acevedo, Colin Allen, Ben Blaylock, Larry Hansen, Nova Silvy, Gary Varner, and Dave Weller.

This page intentionally left blank.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS v

LIST OF FIGURES ix

LIST OF TABLES xi

INTRODUCTION 1

METHODS 2

RADIO-TRACKING 2
Radio Package Specifications 2
Package Mounting 3
Signal Reception System 3
Data Collection 4
Data Analysis 4

PHOTOGRAPHIC TECHNIQUES 5
Study Site 5
Data Collection 5
Data Analysis 7

RESULTS 10

MOVEMENT PATTERNS 12

SURFACING PATTERNS 14

ASSOCIATIONS AMONG INDIVIDUALS 16

BEHAVIOR 18

POPULATION SIZE 19

HEALING OF BIOPSIES 20

DORSAL FIN NOTCHES 20

DISCUSSION 21

MOVEMENT PATTERNS 21

SURFACING PATTERNS 26

ASSOCIATIONS AMONG INDIVIDUALS 27

BEHAVIOR 29

POPULATION SIZE 30

HEALING OF BIOPSIES 31

DORSAL FIN NOTCHES 33

CONCLUSIONS 33

LITERATURE CITED 35

FIGURES 45

TABLES 63

APPENDIX 1. SUMMARY INFORMATION FOR ALL DOLPHINS CAPTURED 77

APPENDIX 2. SUMMARY OF CAPTURE INFORMATION 81

APPENDIX 3. RESIGHTINGS OF NON-RADIO-TAGGED DOLPHINS 85

APPENDIX 4. SEMI-WEEKLY POSITIONS OF RADIO-TAGGED DOLPHINS 91

APPENDIX 5. DIURNAL POSITIONS OF RADIO-TAGGED DOLPHINS 101

APPENDIX 6. SUMMARY OF OBSERVATIONS ON BIOPSY WOUNDS 107

LIST OF FIGURES

Page

Figure 1. Map of the Port O'Connor area of Matagorda Bay 45

Figure 2. Left and right sides of a dolphin dorsal fin (FB502) showing radio package placement (a) and magnesium nuts (b) 46

Figure 3. Example triangulation for FB518 at 1045 hr, 11 August 1992, from Home Base, in Port O'Connor, and a tracking vessel at the base of the western Matagorda Ship Channel jetty 47

Figure 4. Photographic survey effort, May 1992–June 1993 48

Figure 5. Sightings of freeze-branded dolphins across surveys 49

Figure 6a. Summary ranges for radio tagged dolphins FB501 and FB502, from radio telemetry and sightings, May 1992–June 1993, with information on age and sex 50

Figure 6b. Summary ranges for radio tagged dolphins FB504 and FB505, from radio telemetry and sightings, May 1992–June 1993, with information on age and sex 51

Figure 6c. Summary ranges for radio tagged dolphins FB514 & FB515 (1), FB511 & FB522 (2), and FB518 & FB521 (3), from radio telemetry and sightings, May 1992–June 1993, with information on age and sex 52

Figure 7. Positions of FB518 by time of day, 15 June 1992–13 September 1992, from radio telemetry and sightings 53

Figure 8. Approximate noon positions for dolphin FB518, 15 June 1992–13 September 1992, from radio tracking and sightings (two subsequent sightings on bold) 54

Figure 9. Relative frequency histograms of dive durations during day (a) and night (b). 55

Figure 10. Affiliations of all female and calf (a) and male (b) freeze-branded dolphins (as measured by dolphins occurring in the same group in a sighting), May 1992–June 1993 56

Page

Figure 11. Plots of relative percents of behaviors by survey (a) and hour of day (b) 57

Figure 12. Mean group sizes by survey (a) and hour (b), error bars indicate 1 SD 58

Figure 13. Mean group sizes by behavior, error bars indicate 1 SD 59

Figure 14. Histogram of observed travel directions 60

Figure 15. Assumed minimum area occupied by estimated dolphin population 61

LIST OF TABLES

Page

Table 1. Summary of radio tracking effort 63

Table 2. Summary of photographic survey effort 64

Table 3. Summary statistics for surfacing interval data 65

Table 4. Mean half-weight index of association values for non-calf freeze-branded dolphins seen at least five times 68

Table 5. Mean half-weight index of association values for same-sex and opposite-sex associations among freeze-branded dolphins 70

Table 6. Primary and secondary affiliates of the six female and eight male freeze-branded dolphins most frequently sighted 72

Table 7. Observed frequencies of behaviors in each habitat type 73

Table 8. Mean direction of travel for eight surveys 74

Table 9. Bailey-modified Petersen estimates of population size 75

Table 10. Stages of wedge-biopsy healing 76

This page intentionally left blank.

INTRODUCTION

In March and April 1992, 111 bottlenose dolphin carcasses were recovered from the area between Matagorda and Aransas bays of the central Texas coast (Fig. 1). This represented an unusually high mortality, compared to a mean of 14 (SD = 7.7, range = 5–23) deaths during March–April calculated from the previous 5 yr (Elsa M. Haubold, Operations Coordinator, Texas Marine Mammal Stranding Network, personal communication). The die-off raised questions about dolphin movement patterns and site fidelity on the Texas coast, and on the ability of potentially locally depleted stocks to recover through immigration. In response, the National Marine Fisheries Service funded the Marine Mammal Research Program of Texas A&M University at Galveston (MMRP) to conduct a 6-day survey of the Matagorda Bay area. The primary intent of the survey was to obtain data on approximate minimum numbers of animals still alive in the area by photo-identification, general behavior and apparent health of live animals, and the overall feasibility of conducting long-term ecological studies on bottlenose dolphin distribution and habitat use in this bay system.

The short preliminary study, carried out 15–19 May 1992, photo-identified at least 67 different dolphins inhabiting the area; discovered no apparently moribund dolphins among the live animals; and resulted in the strong recommendation that detailed research, relying on tagging, physiological studies, and long-term radio-tag and photographic monitoring were essential to an understanding of dolphin use of the Matagorda Bay environs.

Consequently, to assess the impact of the spring 1992 die-off, a National Marine Fisheries Service-sponsored capture effort from 7–19 July 1992 resulted in collection of physiological information from 36 dolphins (Sweeney 1992, Graham A. J. Worthy, Director, Texas Marine Mammal Stranding Network, personal communication). The 36 dolphins received dorsal fin roto-tags (Scott *et al.* 1990b, Sweeney 1992); 35 were freeze-branded on both sides of the upper dorsum and/or dorsal fin (Odell and Asper 1990, Scott *et al.* 1990b, Sweeney 1992); and 10 were fitted with radio transmitters (Evans 1971, Würsig *et al.* 1991).

The primary objectives of this study were to gather information on range characteristics and site fidelity, and to begin a long-term study of dolphins in the area by examining movement patterns, associations among individuals, and other ecological data. The results of radio-tracking and photographic monitoring are described here. Radio-tracking was from 9 July 1992 to 13 September 1992, when radio signals were no longer received. Photographic

monitoring of freeze-branded dolphins is presented for the periods of May 1992 through June 1993.

METHODS

Matagorda Bay, on the central Texas coast (28°30'N, 97°20'W), is characterized by wide seasonal swings in temperature and salinity. Over the bay as a whole, mean salinity ranges from 12.7 in spring to 16.5 in summer/winter (Orlando et al 1993). In the study area, salinities ranged from $\bar{x}$ = 17.3 ppt (SD = 11.12, n = 119) in spring/early summer to 27.0 ppt in late summer (SD = 6.40, n = 97) (Würsig, unpublished data). Temperature was sampled less frequently but was 12–15 °C (n = 3) in winter and $\bar{x}$ = 31.3 °C in late summer (SD = 1.31, n = 6) (Würsig, unpublished data).

For radio-telemetric and photographic data analyses, statistical tests were run with StatView 4.0fpu (BrainPower 1986) and Excel 4.0 (Microsoft 1992) for Apple Macintosh microcomputers.[1] Two age classes were defined for analytical purposes: "immature" was comprised of females < 8 yr old, males < 10; and "mature" as females ≥ 8 yr old, males ≥ 10. The boundary ages were based on youngest pregnant female captured and age-at-maturity results from Fernandez (1992).

RADIO-TRACKING

Radio Package Specifications

The radio transmitters (Fig. 2), built by Telonics, Inc., Mesa, Arizona, consisted of aluminum tubes 8.0 cm long and 1.6 cm in diameter, with a 0.1-cm thick and 39.0-cm long stainless-steel antenna, topped by a 0.3-cm ball to prevent injury by the tip of the antenna (configuration MOD-050 transmitter package with TAGL antenna). Transmitters broadcast in the frequency range of 148–150 MHz, at a pulse rate of 90/min, pulse duration of 400 msec, bandwidth of 16.2 Hz, and power output of approximately 10–20 milliwatts. Power was provided by sealed lithium batteries designed to last approximately 6 weeks.

The transmitters were attached to a rectangular 12.5-cm long, 4.0-cm high, and 0.12-cm thick aluminum plate rounded at the four corners and backed by 0.4-cm thick open-cell "wetsuit" neoprene. Transmitters were attached to both the aluminum/neoprene plate and the dolphin dorsal fin by two 0.64-cm diameter bolts fabricated from Teflon rods supplied by Cadillac Plastic and Chemical Co., Houston, Texas. On the radio side, the Teflon bolts were

[1] Use of trade-names does not imply endorsement by the National Marine Fisheries Service.

threaded with a stainless steel lock-tight nut. On the opposite side of the fin, the bolts were threaded with a fabricated magnesium alloy nut. The magnesium alloy was supplied by Metal Supply Co., Philadelphia, Pennsylvania. The magnesium nuts were backed by 3.5-cm-aluminum washers, also fitted with neoprene against the skin surface. Between the magnesium nut and the aluminum washer was a 3.5-cm-metal washer to interact electrolytically with the magnesium and salt water. The magnesium nuts were designed to corrode to disappearance within about 4 wk in water 25–30 °C and about 20–30 ppt salinity. The magnesium nuts were 2.6 cm in diameter and approximately 1.0–1.3-cm thick, with the rear nut slightly thinner (by 0.1 cm) than the front nut, so that the front bolt would tend to hold the package a few hours longer than the rear bolt, and not cause an adverse turning and increased drag of the radio package, likely if the rear bolt held longer.

Package Mounting

The radio was mounted to the dorsal fin by the Teflon bolt and aluminum/stainless steel/magnesium nut assemblies. Two 0.60-cm-bolt holes were punched through the fin with a standard stainless steel laboratory cork borer disinfected with Betadine. Prior to hole punching, a veterinarian examined the chosen location for absence of major arteries with an 18-gauge needle, sterilized the site with alcohol, and administered a local anesthetic of 1.8 cc Lidocaine (Sweeney 1992). Slight bleeding occurred about one-half of the time and always stopped upon insertion of the tight-fitting Teflon bolts. The bolts were custom-fit to each dorsal fin by snipping off excess bolt material with wire cutters. The magnesium alloy nuts were finger-tightened and then pressure-crimped with a vice-grip.

Signal Reception System

Dolphin radio-transmitter signals were received with Telonics TR-2 hand-held receivers and Telonics TS-1 hand-held automatic frequency scanning receivers. These were used with antennas ranging from hand-held "H" or two-element antennas (± 20° directional accuracy) to five-element Yagi-Uda antennas (± 5° directional accuracy) on aluminum poles up to 8-m high (Fig. 3). Receiving systems were used from each of two 5.5–7 m outboard vessels, a pick-up truck, several secondary land-based stations, and two five-element antennas on the second story balcony of a house (Home Base) in Port O'Connor, at the southern end of Matagorda Bay (28°27.05'N, 96°25.12'W). Total height of the Home Base antennas was approximately 14 m above sea level, and approximate range of reception varied from 10–20 km. Twin "H" antennas also were mounted on the wing struts of Cessna 172 and Piper Cub aircraft and on the footsteps of a Cessna 177 for aerial tracking. Usual range

was at least 50 km from an altitude of 800–1500 m. Details of tracking from stationary and mobile antenna arrays can be found in Mech (1983).

Data Collection

Directional bearings were taken on each dolphin every 4–6 hr for the life of the transmitter. Bearing entries included notes on signal quality (strength and signal to background noise), estimated distance and location (based on operator experience), environmental conditions, and a 30-min sample of surfacing intervals when signal quality allowed for reliable data. Bearings were often taken simultaneously from more than one location, allowing for triangulated positions. During daylight hours, one of the vessels often approached tagged animals by homing onto the signal. At such times behavioral observations, photographs, and HI8 video recordings were made; and exact positions, useful for comparisons to estimated and triangulated positions, were obtained. These sightings also allowed radio operators at remote locations to calibrate their distance and location estimates. Surfacing intervals were obtained by noting the time, to the second, when the radio signal was first heard as the dolphin surfaced. Also noted was the number of pulses (beeps) received while the dolphin and transmitter were at the surface. Previous and present experience indicate that almost all surfacings lasting < 2.5 sec are accompanied by a single breath. Longer surface times indicate dolphins resting at the surface, or traveling or feeding in extremely shallow (< 0.5-m depth) water.

Data Analysis

Radio-track analysis consisted of plotting telemetered locations onto a map, and visually inspecting for movement patterns, distances traveled, and geographical ranges (the area over which an individual moved in the course of the study). Ranges (Fig. 6) were plotted with Canvas 3.5 for Macintosh (Deneba 1992) by drawing a continuous area covering all telemetered and visually sighted positions. Range sizes were calculated using Canvas' "Calculate Area" command (Deneba 1992) and compared between males and females, pregnant and non-pregnant females, females with calf and those without, and age class (Mann-Whitney *U*). A simple linear regression was performed to investigate potential dependence of range size on number of days tracked for each of the dolphins.

To investigate differences in range use between males and females, we compared variance about the mean position. The mean horizontal and vertical x-y coordinate was determined for each radio-tagged dolphin. Horizontal and vertical deviations from the mean were calculated for each

telemetered and visually sighted position for each animal and compared by a variance ratio *F*-test (Zar 1984).

Surfacing interval data consisted of dive duration, dive rate, and surface duration. Dive duration was measured as the time interval between surfacings. Dive rate was calculated by dividing the number of surfacings by the duration of the sampling period (usually about 30-min). Time spent at the water surface between dives (surface duration) was indicated by the number of pulses heard. Statistical tests were performed on these pulse counts and subsequently transformed into the presented durations in seconds by multiplying the pulse count by 1.5 pulses/sec, the transmitters' pulse rate. The 30-min sampling periods were coded by time of day: "day" = 0700–1900, "night" = 2100–0500, and "crepuscular" = 0500–0700 and 1900–2100.

The three surfacing-interval-data types were averaged for each dolphin over the 30-min sampling periods to minimize dependence within a sampling period. These means were compared statistically by time of day, and among individual dolphins (Kruskal-Wallis, followed by Fisher's LSD); pregnant *vs.* non-pregnant, with-calf *vs.* without-calf, and sex (Mann-Whitney *U*); and age, and across each other (*e.g.*, dive duration was regressed on dive rate and surface duration, simple linear regression).

PHOTOGRAPHIC TECHNIQUES

Study Site

The primary photographic survey area included most of the range of radio-tracked individuals. Areas with particularly high-density coverage were western Matagorda Bay, from Sand Point south to the Matagorda Ship Channel Jetties; and west to eastern Espiritu Santo Bay, including Vanderveer Island and the Ferry Channel. This area also includes the Intra-Coastal Waterway (ICW) near Port O'Connor, and Pass Cavallo (Fig. 1). Survey effort was not uniform (Fig. 4).

Data Collection

Photographic surveys required three people: boat-driver, note-taker, and photographer. Unstructured, meandering censuses were conducted from 5.5- and 7-m outboard vessels. Upon encountering a dolphin group, behavioral and environmental data were collected on a data sheet and dorsal fin photographs were attempted of all animals in the group (Würsig and Würsig 1977, Würsig and Jefferson 1990). Typically, dorsal fins were photographed with a 35-mm camera from distances of 5–15 m with a 70–210-mm-zoom lens, using 200-ISO slide film. An estimated 50–80% of Texas shore dolphins

are identifiable by natural markings (*e.g.*, Bräger 1992). Roto-tags, freeze-brands, and radio transmitters (and subsequent transmitter hole marks) provided reliable means of photographic recognition for those 35 dolphins which had been freeze-branded in July 1992. While radio-tracking was only possible for a part of summer 1992, the naturally and artificially marked dolphins of the area provided a long-term data source by photographic recognition.

A dolphin group was defined as one or more individuals exhibiting the same behavioral state(s) in the same geographical area (sometimes up to a one to two hundred m^2 area, probably within acoustic communication range), usually following a 10-m chain rule. Total number of individuals including neonates and other calves were recorded. Neonates were recognized by fetal folds and uncoordinated surfacing behavior. Non-neonate calves were recognized by their small size (generally a body length $\leq$ 0.75 that of accompanying adults).

Information was gathered on the broad behavioral categories "traveling", "feeding", "feeding behind shrimpboat" (FBS), "socializing", "milling", "bowriding", and "unknown" (and all combinations). Traveling was indicated by steady movement in one direction. Feeding was indicated by behavior oriented towards visible fish, such as chasing or tossing them in the air. Feeding also was suggested by repeated long dives in one location, without seeing fish, though this was often in the presence of feeding seabirds. FBS was indicated by dolphins following a trawling shrimpboat, or feeding on discarded bycatch (Fertl 1994). Socializing was active behavior, indicated by leaps, breaches, and other aerial behavior; sexual, play, or aggressive behavior; and much body contact at the surface. Milling was indicated by low activity levels and lacked components of the above behaviors. Dolphin behavior was evaluated in the few minutes while approaching the group and/or while taking photos.

As part of the health evaluation of captured dolphins, a wedge biopsy of approximately 1 gram of tissue was taken from the dolphin's left flank, approximately 10 cm posterior to, and 10 cm below, the posterior base of the dorsal fin (Sweeney 1992). From photogrammetry, we estimated the shallow, oval shaped biopsies to have been approximately 30 mm long by 20 mm high, though the dimensions varied by several mm among individuals. Healing of biopsy wounds was monitored for the periods of July 1992–December 1993, from photographs of biopsy wounds taken opportunistically during the regular photographic surveys.

Data Analysis

Dorsal fin photographs were categorized by distinctive features such as size, location and position of major notches, as well as by artificially-applied marks (Würsig and Jefferson 1990). Sighting locations were plotted and examined for patterns of range and site fidelity.

Indices of association were calculated for freeze-branded dolphins only by use of the half-weight index of association (Dice 1945, Cairns and Schwager 1987):

$$\frac{N_{ab}}{\frac{1}{2}(N_a + N_b)}$$

where

N_{ab} = the number of times individuals a and b were seen together,

N_a = the number of times individual a was seen, and

N_b = the number of times individual b was seen.

The half-weight index was chosen because it is commonly used, facilitating comparison with other studies; and because it is least biased when individuals of a pair are more likely to be seen separate than together, which we believed to be a good assumption for the dolphin pairs examined in this study (Cairns and Schwager 1987).

A minimum of five sightings of an individual was chosen as a criterion for inclusion in affiliation analyses. We believe that five sightings provide a reasonable number of resightings from which to generalize, given the small sample sizes, without limiting the number of individuals so much as to preclude interesting comparisons. Multiple sightings of an individual in a single day were counted as a single sighting. Numbers of affiliates were examined for differences across sex, females with- and without-calf, pregnant and non-pregnant females (Mann-Whitney *U*); and age, mean half-weight index value, range size, mean group size, and number of sightings (simple linear regression). Mean-index values were compared among dolphins (Kruskal-Wallis) and between sexes (Mann-Whitney *U*). We examined an individual's two "closest" (highest index value) associates for patterns of sex, age, and reproductive condition.

Behavioral states which involved more than a single behavior were scored for each behavioral component. Behavioral categories and dolphin group sizes were examined for variation across each other, survey month, hour of day (0800–1959), and habitat type ("channel": water bodies such as the ICW, Big Bayou, and Saluria Bayou; "jetty": between or within 50 m of either the ICW at Port O'Connor jetties or the Matagorda Ship Channel jetties; "bay": all other bay waters; and "offshore": gulf waters). For groups containing freeze-branded dolphins, further analyses were made for differences by sex, age class, females with- and without-calf, and pregnant and non-pregnant females. Groups containing more than one category of individual (*e.g.*, males and females) were scored for each category. Travel directions, in degrees magnetic, were converted to x-y coordinate vectors and analyzed for differences between survey month (Watson and Williams test, Batschelet 1972:85). The numbers of neonates seen were examined for seasonal trends.

Differences in geographic distribution were examined by plotting sighting locations for males *vs.* females; group size classes of ≤ three, four–six, and ≥ seven dolphins; pregnant *vs.* non-pregnant females; females with-calf *vs.* without-calf; neonates; behavior (socializing, traveling, feeding); and age class.

Estimates of population size were made with Bailey's modification of the Petersen Estimator. The Petersen Estimator is a ratio which states that the number of marked animals recaptured in a sample is proportional to the total number of marked animals in the total population (Blower *et al.* 1981). Bailey's modification is an adjustment for recapture with replacement (Eberhardt *et al.* 1979, Hammond 1986):

Petersen Estimator

$$\hat{N} = \frac{M}{(m/n)}$$

Bailey Modification

$$\hat{N} = \frac{M(n+1)}{m+1}$$

where

$\hat{N}$ = the total population size,

n = the number of animals sampled,

M = the total number of marked animals at large, and

m = the number of marked animals recaptured (including resightings of the same individual).

Ninety-five percent confidence intervals were calculated from Seber (1982):

$$\hat{N} \pm 1.96\sqrt{v}$$

where the Bailey-modified variance, v, is

$$v = \frac{M^2(n+1)(n-m)}{(m+1)^2(m+2)}$$

We utilized information from the radio-tracking study to approximate a closed population, and thus minimize incorrect assumptions in the population estimates. Because survey effort was consistent for only a small portion of the total study area (the region surveyed six times in Fig. 4), population size estimates were based only on resightings from this 13 km² area. The number of dolphins estimated to utilize this area was then assumed to occupy at least the areas of Matagorda and Espiritu Santo bays which lie within the ranges of the 10 radio-tracked dolphins. Further refinements were made by determining the total number marked, M, to be not 35, but 17: sightings of the five calves were not independent of their mothers (except one sighting in June 1993), and 13 freeze-branded dolphins were considered to be non-residents in the radio-tracked ranges, based on photo-identification results.

Slides of biopsy wounds were examined when projected on a screen, or viewed on a light table with a 8x loupe. Observations were made on the size, shape, and coloration of the wounds, and compared over time. Caliper measurements were made on aspects of the wounds, from projected images. These relative measurements were then scaled to measurements of dorsal fin features, the size of which were known from photographs displaying a measurement scale several cm behind the fin, taken during dolphin capture. Biopsy wounds were occasionally compared with same-animal radio-tag and roto-tag wounds. Because the photogrammetric measurements may be inaccurate by several mm, due to photographic perspective and variation among individuals, caution should be used in comparison of the measurements.

For the 36 captured dolphins, the numbers of notches on the posterior edge of each dorsal fin were counted and compared by sex (Mann-Whitney U), age, and (for non-calves seen ≥ 5 times) number of affiliates (simple linear regression). Dorsal fin photographs were taken while the captured dolphins were held for health evaluation. The numbers of notches were counted by viewing these slides with a 8x loupe. Only notches which we believed were

large enough to be seen consistently in typical good-quality field-photographs were counted.

RESULTS

Thirty-six dolphins were captured in July 1992 (biological data from Sweeney 1992). Animals ranged in age from 2–34 yr. Of non-calves captured, females had an older mean age and more variability in age than males (females: $\bar{x}$ = 19.7 ± 9.34 (SD) yr old, n = 11; males: $\bar{x}$ = 12.9 ± 4.89 (SD) yr old, n = 15; t-test P = 0.02). Five mother-calf pairs were caught (three female calves, two male). Four mothers were pregnant, as were two–three other females. All pregnant females were in the first trimester. Five males and five females were radio-tracked. Males ranged in age from 8–19 yr, while females were from 8 to as old as 31 yr (from tooth aging data supplied by NMFS). One 8-yr-old female (FB505) was pregnant, one 31-yr-old (FB521) was mother to a 2-yr-old calf and pregnant, one 19-yr-old (FB511) was mother to a 1-yr-old calf and pregnant, and one 12-yr-old (FB515) was mother to a 2-yr-old but apparently not pregnant. Appendix 1 summarizes the age and sex information for all 36 dolphins captured. Appendix 2 provides a summary of the capture information.

Radio transmissions lasted from a minimum of 13 days (FB505) to a maximum of 61 days (FB518). The mean was 30.7 days, (SD = 16.85, n = 10) (Table 1). As is usually the case with radio telemetry, only rarely was the status of a transmitter or dolphin known when transmissions first ceased. Several transmitters apparently suffered broken antennas before the packages fell off. Four dolphins were seen within 5 wk of transmission cessation still wearing the radios. Radio-tags #4 (FB505) and #5 (FB511), which transmitted for 13 and 21 days, respectively, were seen on 8 August and 5 August, respectively, with broken antennas. Some tags which lasted about 3 wk (FB504, FB522) probably released from the dolphins as planned (FB522 was seen on 24 August without the radio package). The long-lasting 8–9 wk tags quit due to either package release or end of battery life. We received a report of FB501 seen on 23 October still carrying the radio package. FB501 probably experienced much lower salinities than the others due to the amount of time she spent in the semi-enclosed San Antonio Bay. As a result, the release mechanism took longer to corrode than had been calculated. FB518, however, experienced salinities similar to the other dolphins. Behavioral differences (*e.g.*, evasiveness, described below) or chance mounting differences may also account for failure of the packages to release earlier.

When certain radio-tagged dolphins (*e.g.*, FB501, FB505, FB511, FB518) were approached by boat, they displayed pronounced evasive behaviors, especially within 2 weeks of radio attachment. This behavior at times resulted

in the tagged dolphin temporarily leaving the dolphins with which it was encountered. Other dolphins (*e.g.*, FB514, FB521, FB522) were not evasive, however, and allowed the boat to approach them. Dolphins had become much less evasive by week 3. However FB501 and FB518 appeared to be somewhat shy of the vessel throughout their tag attachment time (59 and 61 days, respectively). Most non-radio-tagged, freeze-branded dolphins did not display such consistent evasiveness when encountered, nor did unhandled dolphins. This wariness may have been a response to the tag, but there are few pre-tagging behavioral observations against which to compare. FB501 and FB518 were not noted to be especially evasive in post radio-tracking sightings. Of five group sightings of to-be-radio-tagged dolphins in May 1992, only one group was noted to be evasive of the vessel. In this case, evasiveness was probably attributable to the group's initial behavior. This group, containing FB504, was exhibiting "rest" and/or "slow travel". The other four such groups were "traveling" or "feeding".

All 10 radio-tagged dolphins were monitored in the months after the radio tracking and have been seen without the packages. Damage to the dorsal fin varied from small circular scars, to pierced fins, to significant new notches in the trailing edge, perhaps caused by earlier release of the anterior bolt and subsequent hydrodynamic drag of the radio package.

In addition to the intensive field effort between 6 July and 30 August 1992, eight other photographic surveys were conducted between 14 May 1992 and 18 June 1993. In total, 136.3 hr were spent on the water, 2,236 dolphins in 648 groups with a mean group size of 3.5 ± 2.86 (SD) dolphins were seen, and 4,572 photos were taken (Table 2). Among non-calves, females and males did not differ in number of sightings (*t*-test), nor was number of sightings linearly dependent on age (regression). After 12–14 months, freeze-brands became difficult to read on most adult dolphins; the calf freeze-brands became unreadable 3–4 months earlier.

Many freeze-branded dolphins were resighted (Fig. 5). Six adults and one calf which were later freeze-branded were identified during the initial survey in May 1992. Because of the incomplete and sporadic nature of only several days of visual surveys during each trip, and the geographically unbalanced survey effort (Fig. 4), absence of identified animals in the photo-record is not proof of their absence from the area. On the contrary, the evidence from resightings indicates a high degree of interseasonal site fidelity. One set of animals stands out (Fig. 5, FB523–FB532, five males and five females). None of them were resighted in the year since they were captured and freeze-branded in July 1992. All were captured at the extreme northeast end of the study area, 5.5–20 km northeast of the Matagorda Ship Channel Jetties on Matagorda Peninsula (Appendix 3f). Surveys in the year following the

summer radio-tracking period did not include that northeast section (see Fig. 4). However, an amateur's sighting record from November 1992 and data from an August 1993 survey imply that FB530 periodically visits Saluria Bayou. Data from August 1993 and November 1993 also contain sightings along Matagorda Peninsula of FB524 and FB528, respectively. This indicates that dolphins FB523–FB532 may indeed be resident in Matagorda Bay, but farther northeast than we usually survey. FB523, however, was sighted in May and June 1994, offshore near the Galveston, Texas, jetties (185 km north of her capture site). We also received a report of a freeze-branded (number unknown) dolphin occurring at the Corpus Christi Ship Channel jetties, 100 km south of Port O'Connor, in November 1992.

In the June 1993 survey, FB503, a pregnant female (still wearing a rototag), was seen for the first time without her 2-yr-old male calf, FB508. FB503 was not accompanied by a neonate. FB503's group consisted of FB515 (12-yr-old female who's calf, FB517, died the previous September) and four other unidentified dolphins. FB509 (3-yr-old female calf) was also seen without her pregnant mother, 16-yr-old FB507. Data from a July 1993 survey show that FB503 was once again seen without her calf, in a group of eight dolphins accompanying one of two neonates, and again in August 1993 accompanied by a calf and one other dolphin. Appendix 3 charts sightings of the non-radio-tagged dolphins captured.

MOVEMENT PATTERNS

The radio-tagged dolphins had partially to almost completely overlapping ranges. Mean range size was 140 ± 90.7 (SD) km^2 (Table 1). Ranges of radio-tracked dolphins centered near Port O'Connor in all but three cases (Fig. 6a–c). The exceptions were FB501, adult female, and FB502, adult male (Fig. 6a); and FB504, adult male (Fig. 6b). Dolphins FB504 and FB502 spent most of their time near Port O'Connor and not far from their capture sites, but traversed 20–35 km southwest into western Espiritu Santo Bay and San Antonio Bay on 4 of 21 days and 5–11 of 39 days, respectively (on 5 of the 11 days we located FB502 in western Espiritu Santo Bay/San Antonio Bay; on the remaining 6 days we could not locate him in the Port O'Connor area and we assume that he was in the western Espiritu Santo Bay/San Antonio Bay area out of receiver range, but we did not search there by boat). FB501, however, spent about one-half of her time (18–45 of 59 days) in San Antonio Bay, often close to the Aransas National Wildlife Refuge (ANWR). She traveled rapidly between sites on at least three occasions, and spent time either at the northeastern (near Port O'Connor) or the southwestern (near ANWR) portion of her range. On one occasion she traveled overnight at least 55 km in 12 hr for a 4.2 km/hr average speed. Because the signal of FB501 (and of all others over ~ 20 km distant) could not be picked up by Home Base at Port

O'Connor, we often had to search for her by boat, pickup truck, remote station at ANWR observation tower, or airplane. The other seven dolphins showed more confined ranges, traveling within a usual radius of about 12 km from Home Base (Fig. 6b–c). No differences were found in range size by age, sex, or reproductive condition. A regression of range size on number of days tracked showed a moderate linear correlation ($P = 0.02$, $R^2 = 0.53$, $n = 10$), indicating that range estimates for some individuals might have benefited from further tracking. However, range sizes did not change appreciably for most dolphins past the first week of data collection. In addition, from subsequent photo-surveys we believe that the duration of the radio-tracking effort was sufficient to describe the ranges of most of the radio-tagged dolphins.

Dolphins moved between Matagorda and Espiritu Santo bays via the three linking waterways: the ICW, Big Bayou, and Saluria Bayou (Fig. 1). Telemetry indicates that dolphins used both the ICW and Steamboat Pass to move between Espiritu Santo and San Antonio Bays. FB501 used Ayres Dugout to move between San Antonio and Mesquite Bays (Fig. 6a).

On only three occasions did we obtain evidence of radio-tagged dolphins leaving the confines of the bay system to swim in the open Gulf of Mexico. All three positions were within 1 km offshore of Pass Cavallo, based on signal strength and bearing. FB518 (11-yr old male) was positioned offshore on 20 July 1992, and FB522 (8-yr old male) on 23 July and 29 July 1992. On 29 July, FB522 may have been offshore for 6–7 hr, based on the inability to detect a signal following his initial offshore positioning. Because of errors inherent in positioning dolphins by triangulation (as exemplified in Fig. 3) and the changing influences of habitat structure and climate on signal strength (Mech 1983), movement offshore could in reality have occurred somewhat more or less often.

Males were found in the extremities of their ranges more often than females (for horizontal and vertical coordinates $P < 0.0001$, $n = 863$ male positions, $n = 455$ female positions, variance ratio F-test). FB501 was excluded from this analysis because her "dual home range" movement pattern differed from that of the other radio-tagged dolphins (see below). Similar results for random equal subsamples of male and female positions indicate that the higher male variance is not due simply to larger sample sizes. No differences in geographic distribution were found for pregnancy, with-calf, or age class, perhaps due to small sample sizes. No differences in geographic distribution were found for group size class, behavior, or time of day. That is, mother/calf pairs, or feeding dolphins, *etc.*, were not found in particular areas of the study site.

Diurnality and week-by-week movement patterns were similar within and among most dolphins throughout the study (Appendix 4 and 5). The basic patterns were exemplified by FB518, an 11-yr old male tracked for 61 days. He ranged between the SW portion of Matagorda Bay, from Sand Point to Pass Cavallo, and NE Espiritu Santo Bay (Fig. 6c). He was never tracked beyond 13 km from Port O'Connor and ranged within an area approximately 10 km in diameter, centered at Port O'Connor. There was no strong shift in movement pattern by time of day (Fig. 7), and he showed no overall change in movement pattern throughout his 61-day-tracking period (Fig. 8).

FB518 illustrates several general movement patterns seen in the radio-tracked individuals. (1) Dolphins were capable of, and often did, traverse their range in several hours. (2) A dolphin traveled widely on some days, perhaps crossing its range, while on other days movement was very confined, within 1–2 km^2. This did not appear to have a temporal or geographic pattern. (3) Dolphins tended to spend about 1–4 days in a particular portion of their range. (4) Movement tended to be more confined at night than during daytime. (5) Dolphins tended to visit the extremes of their ranges only in the daytime. The assertions of (4) and (5) may be biased as a result of less sampling effort at night (fewer triangulations and no visual sightings).

The range of FB501 differed from the patterns illustrated by FB518 because FB501 apparently had 2 main areas of habitat use (near Port O'Connor and ANWR, respectively) and traveled through the intervening 30 or so km rapidly. While within one particular area, her movement patterns were similar to those of the other radio-tagged dolphins.

SURFACING PATTERNS

A subsample of available radio-telemetered surfacing-interval data gives an overall $\bar{x}$ = 33.3 sec mean-dive duration (SD = 5.79, n = 10 dolphins, 508 averaged 30-min samples), surface durations of $\bar{x}$ = 6.3 sec (SD = 2.16, n = 10 dolphins, 425 samples), and dive rates of $\bar{x}$ = 2.0 dives/min (SD = 0.30, n = 10 dolphins, 507 samples). See Table 3 for a detailed breakdown of interval data. Dive durations did not appear normally distributed; modes and medians were to the left of means (Fig. 9, $P < 0.05$, Kolmogorov-Smirnov test for normality [Zar 1984:92]). Over 50% of dive durations were less than 30 sec, with maximum dive times reaching over 3 min on rare occasions, and almost exclusively at night.

Dive durations differed between day and night (but not crepuscular hours), and across individuals. Night dives, at $\bar{x}$ = 35.4 sec (SD = 8.43, n = 9 dolphins, 153 averaged 30-min samples), were significantly longer than

the $\bar{x}$ = 32.4 sec mean dives during daylight hours (SD = 5.94, n = 10 dolphins, 291 30-min samples, P = 0.0006, df = 2, Kruskal-Wallis). The significance of the test was mostly due to FB504, FB515, FB514, and FB522, which had night dives longer than day dives by 5–10 sec (Fisher's LSD). Figure 9 shows the difference between night and day dive durations for actual surfacing intervals rather than the averaged samples. There was a lower relative frequency of dives < 10 sec, and higher relative frequency of dives > 50 sec, at night.

The dive durations of individuals were different (P < 0.0001, df = 9, Kruskal-Wallis). Fisher's LSD revealed that dive durations of FB514 and FB521 were different from those of most other radio-tagged dolphins. Dives of FB514 were longer by 6–14 sec, and FB521's dives were shorter by 8–20 sec.

Mann-Whitney U tests indicated no difference in dive durations between males and females, pregnant and not-pregnant females, or females with-calf and without-calf. Dive durations were not linearly dependent on either age or surface duration.

Dolphins spent more time at the surface between dives at night than in the day (P = 0.0053, df = 3, Kruskal-Wallis). Mean nighttime surface duration was 6.0 sec (SD = 4.8, n = 129 surfacings), mean daytime surface duration was 5.1 sec (SD = 2.92, n = 238). The surface durations of individuals were different (P < 0.0001, df = 9, Kruskal-Wallis, followed by Fisher's LSD). Fisher's LSD revealed that FB501, FB505, and FB511's surface durations differed from those of almost all other radio-tagged dolphins. FB501 spent 4.5–7.5 sec/surfacing more at the surface, and FB505 and FB511 spent 3–4.5 sec/surfacing more at the surface than most other radio-tagged dolphins.

Females spent longer times at the surface than males (P = 0.0278, Mann-Whitney U), but showed no difference in surface durations between pregnant and not-pregnant females, or females with-calf and without-calf. Surface durations were not linearly dependent on age.

Longer night dive and surface durations imply less diving at night. This is supported statistically by significantly lower dive rates at night than during day and crepuscular periods (P = 0.0003, df = 2, Kruskal-Wallis, followed by Fisher's LSD).

No differences were found in dive rate between sex, pregnant and not pregnant females, or females with-calf and without-calf (Mann-Whitney U) or among individuals (Kruskal-Wallis). Dive rates were not related to age (simple linear regression). As expected, there was a strong negative relation between dive rate and dive duration (R^2= 0.80, P = 0.0005, ANOVA, n = 10 dolphins).

From boat based observations, surface durations of about 3 sec were strongly correlated with a single breath. Longer surface durations sometimes correlated with two breaths, one at the beginning and one at the end of the surfacing. Occasionally, and especially at night, we recorded surface durations lasting many seconds, to > 1 min. Sometimes a dolphin had its transmitter antenna continuously above water for as long as 3 min. From the tracking vessel, such protracted surface durations were observed in dolphins motionless at the surface and in dolphins foraging in very shallow water (> 0.5 m).

ASSOCIATIONS AMONG INDIVIDUALS

Frequent changes in group sizes and affiliations occurred among these radio-tagged, freeze-branded, and other recognizable dolphins. Almost all affiliations for freeze-branded dolphins seen more than once were below 0.200 on the half-weight index of association, indicating that none of the adult freeze-branded dolphins were close associates. No difference was found in the number of affiliates across sex, pregnant *vs.* non-pregnant, with-calf *vs.* without-calf, or age for non-calves with ≥ five sightings. Both male and female dolphins tended to have more male affiliates than female, and males tended to have more affiliates over-all (for non-calf freeze-branded animals seen ≥ five times and with ≥ four freeze-branded affiliates). Sample sizes were insufficient to show potential affiliation differences by age or reproductive classes.

Affiliations between freeze-branded dolphins only, as judged by occurrence within the same group in a sighting, were weak except for mother-calf pairs (Fig. 10). The mean level of association was 0.12 ± 0.027 (SD) (for non-calves seen ≥ five times, n = eight males, six females). Table 4 shows the 14 dolphins and their mean index values by sex of affiliate and overall.

Thirty-six of a possible 91 (39%) pairwise combinations were sighted. Forty percent (6/15), 43% (12/28), and 75% (18/24) of pairwise combinations were sighted for female-female, male-male, and opposite-sex affiliations, respectively. Resightings of pairs were low: two female-female pairs were seen twice, one male-male pair was seen twice, and six opposite-sex pairs were seen two to three times.

The mean index value (*i.e.*, level of association) did not differ among male-male associations, female-female associations, opposite-sex associations, or associations overall (Kruskal-Wallis, df = 3, P = .45), though male-female pairs showed greater variability in level of association (Table 5).

Mean index value and number of affiliates were not dependent on age (simple linear regression). However, females with many affiliates had more male affiliates than females with lower numbers of affiliates ($P = 0.007$, $R^2 = 0.87$, simple linear regression) while maintaining a similar number of female affiliates ($P = 0.72$, $R^2 = 0.03$). For females, mean index value was not dependent on number of affiliates (split by sex of affiliate: male $P = 0.10$, $R^2 = 0.67$, female $P = 0.72$, $R^2 = 0.04$).

Males with high numbers of affiliates had more male and female affiliates. They had lower index values for female affiliates than males with few affiliates ($P = 0.008$, $R^2 = 0.79$, simple linear regression), yet showed little difference in association levels with other males ($P = 0.72$, $R^2 = 0.02$). Males sighted in larger mean group sizes tended to have more female affiliates than those seen in small groups ($P = 0.046$, $R^2 = 0.512$).

We examined the first and second highest level affiliates ("1°" and "2°" affiliates, as measured by the two highest association indices) of the eight male and six female non-calves seen ≥ five times (Table 6). Sample sizes were too small for statistical tests, so we report here on tendencies. One individual (male FB512) had two 1° affiliates (tied index values, a male and a female) and so was counted twice in some of the following analyses. Eleven of 14 1° and 2° affiliations were of same-sex pairs (7 male-male, 4 female-female). Seven of eight male-male 1° and 2° affiliations were of similar aged dolphins (within 1–3 yr). Four of six 1° and 2° female-female associations were of similar aged dolphins (within 1–4 yr). Two males and 1 female had 1° affiliates of opposite sex. Eighteen of 28 affiliations were reciprocated at the 1° or 2° level (*i.e.*, nine pairs of dolphins). Male-female associations tended to be reciprocated as often as same-sex affiliations.

The 1° reciprocal male-male pair FB502-FB504 had an index value of 0.190 (Table 6). For FB504 this value was > 2 SD's above his mean index value for associations with other males, females, or overall (Table 4). For FB502, the 0.190 value was < 1 SD above mean, perhaps due to small sample sizes. Similarly, the male-male pair FB518-FB522 shared an index value of 0.114 with each other. The index value was > 2 SD above mean for association with other males for FB518 and for associations overall for FB522. FB518 and FB522 were each others' second highest affiliates (a reciprocal 2° pair). For both FB518 and FB522, the 1° affiliate was FB521, a female. The FB518-FB521 association was reciprocated at an index value of 0.146, and was approximately 1 SD above the mean for opposite-sex associations, but > 2 SD above mean for same-sex associations and overall associations, for both individuals. They were seen more with each other than with other freeze-branded dolphins of the same sex, respectively.

BEHAVIOR

The May 1993 survey was excluded due to its brevity. Behavioral budgets are biased to an unknown extent by the behavior "feeding behind shrimpboat" (FBS). The shrimp fishery operates predominantly on summer mornings to early afternoons in the study area (Spencer Lynn, personal observation), and trawling shrimpboats are reliable places to find dolphins (Fertl 1994). Since the primary goal of our field effort subsequent to cessation of radio-transmitters was to photo-identify individuals, effort was often biased towards seeking out shrimpboats.

Table 7 presents the proportion of behaviors seen overall and within each habitat type. Travel represented 50.7% of sightings and feeding 28.4%. Most behaviors were seen in all habitat types. Travel in "jetty" channels was common, as was feeding at the ends of jetties and in "channels".

Dolphins displayed a variety of interesting feeding behaviors, including individuals "herding" fish against cement walls and ship hulls. Most feeding appeared to be at an individual level, though aggregations of dolphins feeding in subgroups of about one to three could be large and spread out over areas of 100 m^2 or more. Several dolphins rapidly converging on one spot could be evidence of coordinated feeding, or a simple strategy of "getting there first". Some feeding was seen in very shallow water (> 0.5 m). On one occasion we observed 4 dolphins "headstanding" in water approximately 1-m deep. Their bodies and peduncles were so far in the air that we believe they may have been rooting in the bottom with their rostrums. Feeding was often seen concurrently with travel. A typical sighting of travel-feed usually involved groups of one to three dolphins traveling slowly in a channel. Individual dolphins would occasionally stop traveling to apparently investigate habitat structure such as channel walls and ships at dock. Often evidence of feeding was then seen. Group mates often continued traveling during the foraging attempt, performing similar activities.

No strong seasonal or hourly trends in behavior or group size were found (Fig. 11 and Fig. 12, respectively). More groups were encountered traveling in July–August and September. Trends may be obscured by bias due to FBS in the May and June surveys, and by spuriously low observations of feeding in January (n = three feeding observations in January but n = 24 the previous December). However, from August through December, a trend for increased sightings of feeding groups is evident. Concomitant with increased feeding is a trend for decreased social activity from May through January (Fig. 11a).

Feeding was common in early mornings but tended to decrease throughout the day, being replaced by socializing (Fig. 11b). There is a curious increase in "mill" and "unknown" behaviors in mid-day, either of which may be related to forage, rest, or social activities.

Group sizes were significantly smaller in "channels" (over all habitat types $\bar{x}$ = 3.5 ± 2.93 (SD) dolphins/group, for "channel" $\bar{x}$ = 3.0 ± 2.54 [SD], $P < 0.0001$, ANOVA, followed by Fisher's LSD). Group sizes were skewed towards smaller groups (median = 2.5, and maximum = 20 dolphins/group over all groups seen). Group sizes tended to be largest in midday (Fig. 12b) and for socializing groups (Fig. 13). No difference in group size was found between age classes, pregnant *vs.* non-pregnant, with-calf *vs.* without-calf, or sex for freeze-branded dolphins; however, sizes of groups containing males had greater variance than did those containing females (with males $\bar{x}$ = 7.3 ± 2.25 [SD], n = 8 dolphins; with females $\bar{x}$ = 6.0 ± 1.40 [SD], n = 8). Biases in behavioral analyses resulting from unequal representation of individual dolphins in the data set can be gauged by sighting frequencies shown in Figure 10.

Travel direction showed a NE/SW bimodality (Table 8, Figure 14), probably an artifact of the geography of the study site, which is essentially a corridor with NE/SW orientation. Analysis of behavior by sex, age, pregnancy and with-calf was inconclusive, perhaps due to small sample sizes. Frequencies of behaviors were not significantly different between males and females (P = 0.06, Mann-Whitney U). Excluding May 1993, of all surveys between July 1992 and June 1993 (Table 2), neonates were seen only in the July–August and September 1992; and June 1993 surveys. The proportion of neonates to other dolphins was $\bar{x}$ = 0.02 ± 0.028 (SD) (n = 8 surveys).

POPULATION SIZE

Mark/recapture data indicate that of 409 dolphin sightings during surveys not biased by radio-tracking, there were 31 resightings of freeze-branded animals. Bailey mark/recapture population size estimates ranged from 101 (June 1993) to 434 (October 1992) (Table 9). Over all six surveys, representing 13 months, the estimate was 218 dolphins. Figure 15 shows the area used for making "recaptures" (resighings) and the area which the 218 dolphins are assumed to occupy. As a comparison, "unrefined" estimates, based on M = 30 with resightings from the entire survey area (all shaded areas in Fig. 4), yield Bailey estimates of 370 (January 1993) to 1,161 (October 1992).

Our method of approximating geographic population closure gives an indication of the amount of dolphin use of the area, implying that in a year's

time, 218 individual dolphins may utilize the small 13 km^2 shaded region of Figure 15.

HEALING OF BIOPSIES

Biopsy marks of 16 individual dolphins were photographed 1–4 times post-biopsy, spanning from eight to 476 days elapsed time (Appendix 6) yielding 27 post-biopsy photographs. Table 10 groups observations from these 27 photos, plus two photos of fresh biopsies, into four stages of wedge biopsy healing.

Biopsies were approximately 30-mm long by 20-mm wide. A fresh biopsy appeared pink to red, oval shaped and several mm deep. Eight to 18 days post-biopsy, the oval wound was whitish with some pinkish coloration remaining. The center of the wound was a darker spot measuring 4–5 mm in diameter. The skin at the edge of some of these stage 1 wounds was darker than the surrounding normal skin in a 2.7–3.3 mm band. The wound, including dark band, may also be surrounded by a halo of lighter gray skin, gradually fading into normally pigmented skin. By days 15–26 post-biopsy (stage 2) all pink coloration was absent. The central dark spot (3.6 mm diameter) and light gray halo (3.9 mm band) remained. In stage 3, at 40–42 days, a white spot remained, with no other discoloration. By stage 4 (> 61 days), pigmentation of the wounds was normal or nearly so. An indentation a few mm deep was still present in the blubber layer of one individual, FB517, recovered dead (see Appendix 3).

Epidermis appears to have covered the entire wound by day 40 (stage 3) and at least by day 61 (stage 4), but possibly as early as day eight or 15 (stage 2), judged by the absence of pinkish coloration and smooth appearance of the wound. The new epidermal layer, which covers the wound before the underlying blubber layer is fully filled-in, is repigmented in stage 3.

DORSAL FIN NOTCHES

The number of notches on the trailing edge of a dolphin's dorsal fin was not different between males and females (P = 0.69, Mann-Whitney U, n = 20 males, 16 females). The exclusion of calves did not affect this analysis. Mean number of notches was 5.9 ± 2.77 (SD) (range 0–10, n = 36 dolphins). There was a tendency for older males to have more notches than younger males (P = 0.0014, R^2 = 0.44, simple linear regression). This trend was not noticeable in females (P = 0.12, R^2 = 0.16). Females (excluding calves) with more female freeze-branded affiliates showed a tendency to have more notches than those with fewer female affiliates (P = 0.06, R^2 = 0.61). No trend

was evident for the number of male affiliates. For males, number of notches was not linearly dependent on number of affiliates.

DISCUSSION

Radio transmitter life spans of 13–61 days made possible a detailed analysis of ranges, individual interactions, diurnal behavior, and habitat preferences of 10 bottlenose dolphins in a warm temperate inshore ecosystem. Tracking 10 or nearly 10 dolphins simultaneously resulted in a better overall capability for analysis of affiliations and overlapping ranges than has been accomplished for dolphins in the past via radio-tracking. We attribute the success of the tagging/tracking work to a combination of package design and to an experienced, dedicated research team in the field. Often in past studies, tag design, especially of the antenna attachment; package attachment; or follow-up tracking were faulty. These problems were minimized for this work. We recommend that even very small transmitter systems be attached for not more than 2-3 months, to avoid adverse reaction of the dolphins to the package, by chafing or otherwise hindering the animals. Antennas and packages will always be subject to tremendous stresses when dolphins leap, rub along the bottom, or engage in boisterous social-sexual play.

Some radio-tagged dolphins were wary of the research vessels, including boats which were not present or which had the engines off during capture and processing. The avoidance was variable; it did not appear dependent on age, sex, or reproductive status. Evasiveness has been noticed before, reported as strong in animals with large radio packages (Würsig 1982), intermediate with intermediate "cigarette box" size packages (Norris *et al.* 1985, 1994), and variably weak in the present situation. We have no explanation as to why some dolphins appear to have no adverse behavioral response to tagging while others seem quite disturbed by it. We also do not know how the tag may affect normal movement and behavior patterns. However, we observed all behavioral states, including socializing and bowriding, in radio-carrying dolphins.

MOVEMENT PATTERNS

The ranges of most dolphins were about 20 km in diameter for seven animals, and 50 km in diameter for three animals. Ranges overlapped strongly for all 10 of the radio-tagged dolphins and most of the other freeze-branded dolphins; except for the 10 individuals caught in the extreme northeast of the study area, which apparently did not frequent the Port O'Connor area or eastern Espiritu Santo Bay.

While reports of residency are ubiquitous in the literature, measurements of geographic area commonly used by individuals are rarer. Researchers at two study sites have provided precise estimates of dolphin ranges. On the California coast, individual dolphins commonly range over ≥ 50–483 km of coastline (Defran *et al.* in press) in a 0.5-km-wide strip (Hansen and Defran 1989). Following a 1982 El Niño-related range extension, some individuals have been seen to make a 1,340 km round-trip from San Diego to Monterey over about 70 days (Wells *et al.* 1990). Hansen (1983) considered some dolphins to be resident to the 155-km strip around his La Jolla study site during his 17 month study. Nine individuals have been consistently resighted in Monterey through 1993 "suggesting a degree of site fidelity not previously documented for Pacific coast bottlenose dolphins" (Scott *et al.* 1993). Range boundaries may be delineated by depth or distance from shore (offshore boundary, Weller 1991), temperature (northern boundary, Wells *et al.* 1990), and physical or hydrographic features (southern boundary, Caldwell *et al.* 1991). No seasonal movement patterns have been found (Hansen 1990). Hansen (1990) notes that range boundaries delineated by topographic features "are not inviolate and may in fact just correlate with preferred areas".

On the Florida gulf coast, the population is hypothesized to be structured into geographically adjacent "communities" with some social mixing and geographic overlap (see summaries in Scott *et al.* 1990a, Wells 1991). The Sarasota Bay area community consists of approximately 100 individuals, ranging over 100 km² to about 1 km offshore (Wells 1991). Range boundaries seem to be delineated by water depth (Wells *et al.* 1987). Individuals in different age and sex classes have different sized "core use areas" which seem to be on the order of 50–100 km² (Wells 1991). Within the community home range, individuals show tendencies for seasonal habitat use patterns probably related to prey and predator movements (Irvine *et al.* 1981).

In the present study, radio-tagged dolphins had two distinct range areas (Fig. 6). This is consistent with Gruber's (1981) hypothesized "extended herd home ranges" with shared borders in the Port O'Connor area. For example, FB515 stayed mainly in the NE section of Espiritu Santo Bay and FB514 in an adjoining area in SW Matagorda Bay (Fig. 6c). Both were originally captured together in the small overlapping area. Ranges for FB518, FB521, FB511, and FB522 all overlap strongly. These dolphins were caught together (FB518, FB521) or in areas only 4 km apart (FB511, FB522). A third "extended herd home range" to the northwest along Matagorda Peninsula is suggested by the lack of resightings of 10 of the 11 individuals captured there (Appendix 3f). These 10 were not seen in the following year, perhaps due to lack of effort northwest of our primary study area; data from later surveys indicate that some of them may have been present, as discussed below. The 11th dolphin, FB522 (radio-tag #10), seldom frequented that area in the remainder of his

radio's life span. The hypothesized "extended herd home range" boundaries in this study correspond well with those of Gruber (1981:52). Individually preferred areas were also hypothesized by Shane (1977) and Price-May (1993) for the Port Aransas, Texas area.

Bottlenose dolphins in Matagorda Bay show intriguing parallels to the Sarasota Bay community. The mean 140 ± 90.7 (SD) km^2 range size for individuals in the present study is similar to ranges in the Sarasota area. The Sarasota community is composed, in part, of several "bands" of females and their calves. Some bands contain more than one matriline. In the Matagorda Bay area, evidence of several "extended herd home ranges" within at least 312 km^2, overlapping near Port O'Connor, could correspond to the adjacent communities hypothesized to reside along the Florida west coast, or to the matrilineal bands seen within the Sarasota dolphin community. Dolphin movement ranges in Matagorda, as revealed by radio-tracking, appeared very similar to early radio-tracking results in Sarasota Bay (Irvine *et al.* 1981). In both studies, individual dolphins used separate but somewhat overlapping regions of the bays, and individual ranges were on the order of 100 km^2. The radio-tracked ranges in Irvine *et al.* (1981) for Sarasota Bay corresponded generally to what, with more data, came to be recognized as female band ranges, shown in Wells (1991). Wells *et al.* (1993) reported a "mosaic of overlapping home ranges" for individuals in Sarasota and neighboring communities.

A "dual home range", similar to that of FB501, was described by Caldwell and Caldwell (1972:64) for an albino bottlenose dolphin known from Saint Helena Sound, South Carolina (Essapian 1962) and Georgia waters, a minimum 60-km-traveling range.

Shane (1977), Gruber (1981), and McHugh (1989) report very limited movement in either direction through passes linking Texas bays with the Gulf of Mexico. Würsig (unpublished data) indicates that this type of movement by "resident" dolphins may be more frequent for Galveston Bay. Data from the present study suggest that such movement by these apparently resident dolphins does occur, but infrequently, lasting on the order of several hours, and to an unknown distance offshore (but probably within a few kilometers). The radio tracked dolphins of the present study were not observed to leave the bay system to feed (for example) in oceanic waters. This is an important finding, for it indicates that—if true for a large part of the inshore animals—these dolphins are potentially susceptible to localized toxin input from agricultural runoff or industry. If ongoing studies indicate that the 35 freeze-branded dolphins have long-term (across year) site fidelity for all activities, including feeding, this potential habitat influence may be judged to be even greater.

Dolphins in Matagorda Bay (but not necessarily other Texas bays) may show less offshore movement than in Sarasota, Florida, where the community home range is considered to extend 1 km offshore. Dolphins in the Indian/Banana River system on the Florida east coast showed no movement offshore in surveys conducted between August 1979 and October 1981 (Odell and Asper 1990).

There was a greater geographic spread of male dolphin sightings (variance ratio *F*-test). If we assume capture and sampling biases were small between the sexes, this pattern might arise from two different behavioral traits: (1) males have larger ranges than females (not supported statistically) or (2) range sizes are similar for both sexes but males visit more of their range more frequently or for longer periods, and are therefore more likely to be found in a wider distribution. Male dolphins in Sarasota Bay have shown both traits (Wells *et al.* 1987, Wells 1991). The "resident male pattern" was typified by lone males associating frequently with females and remaining in the relatively limited area within which females ranged. The "roving male pattern" was characterized by males who roamed throughout the community home range. The "resident males" were seen with reproductively receptive females more than the "roving males" (Wells *et al.* 1987). It is possible that the patterns have to do with sexual maturity and obtaining mating opportunities.

We believe that most of the marked dolphins were resident to the area during the major study, and sporadic sightings throughout the year and from unanalyzed surveys through August 1994 indicated longer term residency as well. However, a bias may exist if the 35 marked animals were not collected at random from the population. Certain biases were inherent in the dolphin capture procedures. All animals were caught in or very near water shallow enough for humans to stand, a requisite for the surround-net capture method (Asper 1975). For dolphin and human safety, the capture effort avoided dolphin groups of greater than five individuals and groups containing dolphins less than one year old (Sweeney 1992). It is possible that these shallow-water dolphins displayed more site fidelity than dolphins found in deeper waters of the bay, and that interchange with other bay systems and with the open ocean may be greater than indicated by this subsample. Such biases may also explain why we apparently captured older females than males.

Coastal bottlenose dolphins appear to have "home ranges". Range size and dolphin movement patterns have been hypothesized to be dependent upon reproductive (Scott *et al.* 1990a) and/or forage (Scott *et al.* 1990a, Weller 1991, Balance 1992, Bearzi and Notarbartolo di Sciara 1993) resources. All coastal studies using some form of individual identification show resighting

of individual dolphins (*e.g.*, Shane 1977, Würsig and Würsig 1977, Acevedo-Gutiérrez 1989, Harzen 1989, Peddemors 1989, Ballance 1990, Bel'kovich 1991, Delgado 1991, Rudin *et al.* 1991, Wells 1991, Smolker *et al.* 1992, Bearzi and Notarbartolo di Sciara 1993, Curran *et al.* 1993, Mallon-Day 1993, Swingle *et al.* 1993, Bräger *et al.* 1994, the present study, Defran *et al.* in press). Across studies, there is variation in resighting rate, which seems to correlate with range size where such information is available (*e.g.*, Weller 1991, Wells 1991, the present study). For most study sites, one cannot yet conclude "lifetime" residency, and there will always be differences among individuals, but many sites show residency over several years (*e.g.*, Golfo San José, Argentina [Würsig and Harris 1990]; Sarasota Bay, Florida [Scott *et al.* 1990a]; California coast [Weller 1991]; and Shark Bay, Western Australia [Smolker *et al.* 1992]. In Texas, resightings for a few well known individuals have spanned 6 yr (Galveston Bay, Fertl 1993) and 15 yr (Aransas Pass, L. Price-May personal communication). Our results indicate that long-term residency may be a habit of many within-bay bottlenose dolphins on the Texas coast.

Although dolphins were not radio-tracked out of the study area south of the Aransas National Wildlife Refuge, we received a report of a freeze-branded (number unknown) dolphin occurring at the Corpus Christi Ship Channel jetties, 100 km south of Port O'Connor, in November 1992. Other evidence of occasional long-distance movements along Texas comes from several sources. Gruber (1981) describes a Matagorda Bay sighting of a dolphin originally identified by Shane (1977) in the Corpus Christi area. Jones (1991) describes two dolphins that were resighted at Gulf inlets 517 km and 622 km from where they were initially identified. Jones (1991) found that 11 of 146 identified dolphins occurred at two or more inlets, and all but the above two long-distance movements were of distances < 300 km. The May 1992 and May 1993 Matagorda Bay surveys yielded identifications of two dolphins that had been previously seen in the South Padre Island area, 285 km south (Würsig unpublished data). Finally, FB523 was photographically documented in Galveston waters in May 1994. At present there is little information on how the long-range movement exhibited by some dolphins interleaves with possible long-term residency to relatively small geographic ranges of other individuals.

In California, such long distance movements seem common (Defran and Weller 1993). Similar long distance movements are reported sporadically from other areas as well. Dolphins in the Moray Firth, Scotland, are known to travel 225 km (Curran *et al.* 93). Dolphins in Golfo San José, Argentina, were seen to travel 600 km round-trip (Würsig 1978). The sporadic nature of these reports may be due to lack of effort more than rarity of long-distance movement.

On the southeast US coast, nearshore bottlenose dolphins migrate seasonally (Kenney 1990). They travel northward in the summer as far as Delaware Bay, New Jersey, and southward in the winter, where they range into Florida (Mead and Potter 1990, Mallon-Day 1993). Seasonal density changes have been found in Texas bays, as discussed below, but nothing is yet known about the source of the arriving dolphins or the destination of those departing. It is not known whether migration is inshore between bays, coastally longshore, or directly offshore.

SURFACING PATTERNS

Mean dive durations on the order of 20–40 sec, as we have found, are common in coastal bottlenose dolphins (*e.g.*, Shane 1977, 1990, Würsig 1978, Ballance 1992). Though occasional radio-telemetered dives may be spuriously long (dolphins were seen to surface for a breath without exposing enough antenna for a signal to be received) maximum dive durations of around 3 min have also been observed in Sado Estuary, Portugal (dos Santos and Lacerda 1987). Several studies have shown different dive durations and surfacing patterns to correlate with different behaviors (Shane 1977, 1990, Ballance 1992). We hope that further analyses of the surfacing interval data by members of the MMRP will provide a link between surface duration and number of respirations, and an eventual ability to ascertain general behavior by a description of remotely-sensed telemetry information when correlated with the behavioral observations made by the tracking vessel.

We found longer dives during night than in the day. Long night-time dives by dolphins living near or beyond continental shelf waters often signify increased feeding (Würsig and Würsig 1979, 1980; Norris *et al.* 1985). In the present study, a difference of only a few seconds would seem to be of little biological significance. However, the data are means of means, which tends to reduce variability; and, taken together with longer surface durations and lower dive rates at night, we believe that longer average nighttime dives may be related to resting. While no evidence of a diurnal difference was reported for radio-tagged dolphins in Sarasota Bay, Florida by Irvine *et al.* (1981), Rossbach *et al.* (1993) found longer dives and more time submerged in the afternoon/evening than in early morning for one satellite tagged individual in Tampa Bay, Florida.

Some long dives were interspersed with protracted surface times (many seconds, to minutes). These tended to occur more frequently at night, but we also have observed protracted surface durations exhibited by dolphins resting, or feeding or traveling in extremely shallow water (< 0.5 m deep) in the daytime. Irvine *et al.* (1981) also report that dolphins stayed at the surface for minutes at a time in the Sarasota area. We recorded longer mean surface

durations in some individuals. If the longer durations are due to more protracted times at the surface, then this could indicate that individuals differ in their resting and/or feeding behavior.

ASSOCIATIONS AMONG INDIVIDUALS

While the association index values did not show many differences between males and females, among freeze-branded dolphins; males with many affiliates tended to have higher numbers of both male and female affiliates and to spend less time with females than males with few freeze-branded affiliates. At a low level, some females (*e.g.*, FB515, FB521) associated with many freeze-branded males, and some males (*e.g.*, FB504, FB518, FB538) associated with many freeze-branded females (Table 4, Fig. 10).

Dolphins showed intriguing commonalities with their two highest level associates. A dolphin and its 1° and 2° affiliates tended to be of similar age, especially for males. Eleven of 14 1° and 2° affiliates were of same sex pairs. Some affiliations were greater than one and two SD above mean index values. Several studies have considered affiliations > 1 SD above mean to be "significant", using that level to establish sociobiologically important groupings of individuals (Heimlich-Boran 1986, 1993, Wells *et al.* 1987, Weller 1991). However, values < 0.2 are generally not considered biologically significant (*e.g.*, Weller 1991, Smolker *et al.* 1992).

Bräger *et al.* (1994) found mean index values of 0.125 among affiliations of 35 naturally marked dolphins in the Galveston Bay, Texas, area in 1991. Approximately 63% of 595 possible pairwise combinations were not seen. Approximately 70% of the sighted pairs had index values between 0.001 and 0.190, 23% between 0.200 and 0.390, and an additional 7% between 0.400 and 1 on the half-weight index. Some high level associations were apparently stable over at least 19 months.

Wells *et al.* (1987) and Wells (1991) report moderate index values (*e.g.*, 0.310, 0.560) among "female band" members, values in the 0.450–0.750 range for "strongly bonded" adult males, and values of 0.080–0.100 (0.150 considered high) for male-female affiliations in Sarasota Bay, Florida. The majority of sighted pairwise combinations were between 0.010 and 0.200, and the average number of affiliates was 60.5 (Wells *et al.* 1987). Some high-level same-sex associations have been seen to be stable (*i.e.*, high index values remained high) at least 10 yr (Wells 1991). Variation was found in association patterns with age/sexual-maturity for males and females.

In Shark Bay, Western Australia, Smolker *et al.* (1992) report that approximately 80% of possible pairwise combinations were between 0 and

0.200. While it is unclear what percentage of affiliations were > 0 and ≤ 0.200, Smolker *et al.* (1992) describe the 0–0.200 range as indicative of inconsistent associations. Index levels of approximately 0.210–0.400 were found for female-female affiliates in general. Values of approximately 0.510 were found for high-level female-female affiliates ("cliques"). Index values for male affiliates were spread between 0.210–1. Index values for males forming "male alliances" were 0.800–1 (Connor *et al.* 1992). Male-female affiliations were generally in the 0.210–0.400 range. Some high level associations have been stable for at least 5 years. Differences were found in the association patterns of males and females. Smolker *et al.* (1992) did not use sightings of single dolphins (or feeding dolphins) in computing their index values. This will tend to lower the index's denominator (see Methods) and so raise the values, relative to other studies.

A six year study in the San Diego, California area (Weller 1991, Defran and Weller in press) lacked the frequent long-term high level associations seen in Sarasota and Shark bays. A relatively small number of possible pairwise combinations were not seen. For 160 dolphins, only 38% of possible pairwise combinations fell between 0 and 0.090. Thirty-three percent fell between 0.100 and 0.190. Seventy-one percent of all possible pairwise combinations were below the 0.190 index level. Mean index values for all affiliations for individuals ranged from 0.135 to 0.299, with the majority of mean index values from 0.177–0.239. Dolphins tended to associate with many of the dolphins in the population; number of affiliates increased with number of sightings (to 259 of 373 identified dolphins for one dolphin by the end of the study). Some relatively high-level but short-term affiliations were seen. Associations with index values of around 0.500 were estimated to have durations of 1–48 months minimum for 20 of 40 reciprocal 1° affiliates. Low resighting rates (66% of identified dolphins seen about once per year) contribute to uncertainty about strength and duration of affiliations.

In all of the above studies, many pair combinations have low, but non-zero index values, indicating that for coastal populations of bottlenose dolphins, most individuals have probably "met" each other. Unseen pair combinations (those with index value = 0) may actually occur, but at undetected levels. In Galveston, where the percent of unseen pairs was relatively high, the number of possible pairs not seen dropped from about 72% in 1990 to about 63% in 1991. Mean index value for sighted pairs fell from 0.154 to 0.125 "probably from additional low-level associations being discovered" (Bräger *et al.* 1994). In all studies, the number of low-level associations (those between 0–0.200) has been on the order of 70% of all possible pairs (approximately 100% in the present study).

While average index values for Matagorda Bay dolphins ($\bar{x}$ = 0.119 ± 0.027 [SD]) were similar to overall average values in other studies, the moderate and high values seen in Galveston, Sarasota, Shark Bay, and San Diego for some non-mother/calf pairs and differences in these values with age and sex were absent. By looking only at *freeze-branded* dolphins, caught nearly at random with respect to each other, the present study has examined affiliations between what constitutes a nearly random sample of the local dolphin population. Other studies, however, have examined indices of association among the subgroup of dolphins with the highest sighting rates (*e.g., all* dolphins seen ≥ five times). This latter method is more likely to discover high-level associates since such pairs of individuals will have similar sighting frequencies, as they are often seen in the same group. Clearly, close and long-term associations (indicated by consistent high index values) are not lacking among Matagorda Bay dolphins. Gruber (1981) documented several, as did Shane (1977) in Aransas Bay, and Fertl (1994) and Bräger *et al.* (1994) in Galveston Bay. While we are unable to determine how our examination of patterns among freeze-branded dolphins only has influenced these results, we suspect that as data from naturally-marked individuals is incorporated, Matagorda Bay, which already shares characteristics of its habitat with Sarasota Bay and other sheltered estuarine study sites, will be seen to share life history characteristics of its dolphins as well.

Group composition was not static. Some individuals had as many as 10–13 freeze-branded affiliates over the course of the year. All but four non-calves sighted ≥ five times had > five freeze-branded affiliates, and a high percentage of potential pairwise combinations was seen. The low association indices, high numbers of affiliates, and variable group sizes reveal a fluid social structure for these resident dolphins. Confirmation of tendencies awaits results from naturally marked individuals. Dolphins of the Matagorda/Espiritu Santo/San Antonio Bay complex probably know each other well, and often feed and socialize together. They may easily share tainted prey, disease vectors, or exposure to anthropogenic toxins and contaminants which could contribute to massive die-offs similar to that which occurred in Spring 1992. Similarly, parasite occurrence may be quite equally distributed among adults of the area.

BEHAVIOR

Other studies on the Texas coast consistently indicated high levels of feeding in the morning, high levels of socializing in the afternoon, and more time spent feeding with less socializing traveling in winter months (Shane 1977, Gruber 1981, Bräger 1993). Increased feeding in colder seasons was hypothesized to offset increased thermoregulatory demands (Bräger 1993) or

to reflect increased foraging due to decreased prey availability (Gruber 1981, Bräger 1993). Radio-telemetry in the present study indicated lower activity levels at night. However, low activity levels at night is not a rule for dolphins in Matagorda; FB503 was tracked overnight and traveled 55 km in 12 hr.

Sampling biases in the present study may have contributed to weak patterns. While photo-identification surveys of this type are not a substitute for behavioral studies, our results from Matagorda do fit patterns for both seasonal and hourly behaviors seen in other Texas studies, and in other coastal studies as well (*e.g.*, Shane 1990, Rudin *et al.* 1991, Bearzi and Notarbartolo di Sciara 1993). Feeding, often done individually or in small groups (*e.g.*, two–five dolphins), usually takes up a large proportion of the day, especially in the morning. Group sizes tend to be larger for socializing groups (on the order of 5–15 dolphins). Social behavior tends to occur after feeding in mid-day or evening. Travel may be extensive on less productive coastlines (Würsig and Würsig 1979, Ballance 1992).

Waples *et al.* (1993), in Sarasota Bay, Florida, identified six habitat types and found, as did we, that the majority of travel occurred in channels and the majority of milling occurred in bays. They found the majority of feeding to occur in shallow bay waters. We found the majority of feeding to occur in channels, but, while we did not examine depth as a habitat characteristic, the majority of observed feeding in bays occurred in shallow water near shore. In the present study, channels had a higher proportion of sightings than bays, but this may reflect "sightability" or effort rather than a habitat preference. However, except for FBS, feeding occurred more often in channels than in bays. The additional habitat structure inherent in channels and jetties may support more prey. In our study site, most channels and jetties are also deeper than the bays and so concentrate prey in colder weather.

The summer peak in neonate sightings concurs well with pregnancy data from dolphins caught in July 1992 (all first trimester, n = six), and with a spring peak derived from stranding data for the entire Texas coast (Fernandez 1992). Most studies report low levels of neonate sightings throughout the year, with peaks during spring/summer or summer/fall. Data combined from captive and free-ranging bottlenose dolphins in the northern hemisphere showed a trend for births to be earlier in the year and have less variability in timing with increasing latitude (Urian *et al.* 1993).

POPULATION SIZE

The population estimates (Table 9) do not show a clear sinusoidal seasonal change. Any such patterns may be masked by the large confidence intervals or by extrapolating over large areas, as we have. Yet, encounter rates

(#Dolphins seen/#Hours on water, Table 2) and the October estimate, indicate an autumn increase in the number of dolphins in the Port O'Connor area. Gruber (1981), in the Port O'Connor area, and Shane (1977) and McHugh (1989) in the Aransas Pass area 100 km south, found fall/winter increases and spring/summer decreases in dolphin numbers. Jones (1988), in the Galveston area, 200 km north of Matagorda, found higher autumn numbers. These changing abundances may be attributable to low level, short range migratory movements to warmer waters (Jones 1988) or to a reaction to changing prey densities (Gruber 1981). Further radio-tracking and photographic identification studies are necessary to elucidate subtleties in and sources of seasonal patterns.

Gruber's (1981) population estimates for the 75 km^2 area surrounding Port O'Connor ranged from 93.4 ± 5.39 (SD) dolphins (1.2 dolphins/km^2) in winter to 48.6 ± 19.25 (SD) dolphins (0.6 dolphins/km^2) in spring, from boat-based subarea counts. Our estimated population is assumed to range over 312 km^2, yielding similar densities. Note, however, that dolphins are not uniformly distributed over the area but are found more frequently near shorelines and channels. Sarasota Bay also has densities on the order of one dolphin/km^2, and is a very similar barrier island/estuarine habitat.

We do not know if the study area (shaded areas of Fig. 4) represents an area enclosing most of a breeding population. We assume not, since 10 dolphins tagged in the northeast of this area were never resighted in the area, and were presumably resident further northeast in Matagorda Bay. As well, the extended ranges of some individuals and infrequent sightings of recognizable dolphins in other than their core areas (*e.g.*, Jones 1991), argue against group isolation.

HEALING OF BIOPSIES

We saw no obvious signs of infection in either biopsy or tag wounds. As a rule, the radio-tag (and probably rototag) wounds healed slower than the biopsy wounds, though it is evident that healing of the three wound types went through similar stages (Appendix 6). The radio-tag and rototag wounds differed from wedge biopsies in several ways. Radio-tags and roto-tags are piercings involving foreign material passing through and pressing against skin and connective tissue of the dorsal fin, not blubber, for several weeks' duration. Scott *et al.* (1990:508) note that "tags that break the skin can wick bacteria into the wound and prevent it from healing". Hindered cleansing of the tag wounds may contribute to slower healing rates as well.

Bruce-Allen and Geraci (1985) report on a controlled study of morphology, hematology, and ultrastructure of healing of 2 mm deep scalpel

cuts in captive bottlenose dolphins. They examined the wounds at 1, 3, 7, and 10 days. While Bruce-Allen and Geraci examined very shallow lacerations in captive animals over a short period of time, some interesting morphological parallels to the present study are apparent.

After 6 hr the wounds studied by Bruce-Allen and Geraci had "raised, sharp black edges". By day 1 the dark lines were more pronounced. In the present study, the darker skin surrounding the wound seen in stages 1 and 2 (Table 10) may correspond to the darker skin seen by Bruce-Allen and Geraci through at least day 2. By day 3 of the Bruce-Allen and Geraci study, a thin, poorly pigmented epidermal layer had completely covered the experimental laceration. The larger and deeper biopsy wounds of the present study's free-ranging dolphins may have been covered by new epidermis as early as day 15. On day 7 of the Bruce-Allen and Geraci study, the epidermis was well healed, but the lacerations were white in color and "a .5 cm medium gray halo remained, blending into the surrounding tissue". We observed a similar gray halo in stages 1 and 2 (days 8 to 26), measuring approximately 4 mm wide. On day 10 of the Bruce-Allen and Geraci study, wounds were becoming repigmented and the lacerations were visible as a "white linear mark bordered by a narrow dark gray band". In the present study, the entire surface area of the wounds was repigmented by day 61.

Bruce-Allen and Geraci concluded that healing in bottlenose dolphins was not dramatically different from that of terrestrial mammals, undergoing similar histological and ultrastructural stages and that, at least for cutaneous wounds, healing occurred at rates similar to terrestrial mammals. The lack of color was associated with "pale, unaligned spinous cells with diffuse [not perinuclear] melanosomes" (Bruce-Allen and Geraci 1985). One point of departure from healing in terrestrial mammals was noted by Bruce-Allen and Geraci. They found no scab, but instead a transformation of exposed epidermal surface to degenerating cells with vesicles. They hypothesized that this served as a buffer between the saltwater environment and healing tissue.

Sample size limitations precluded comparisons within and among individuals; and across sex, age, health, and reproductive condition classes. It is interesting to note, however, that the dolphin which received the poorest heath evaluation, FB517, provided the earliest datapoint in the final healing stage of Table 10 (61 days post biopsy). Poor health may not hamper healing of deep wounds to the blubber layer.

Behavioral responses of the dolphins were monitored during the physiological processing, which involved bringing the dolphins aboard a boat (Sweeney 1992). The responses were generally calm, but some animals became agitated enough that processing stopped early or was finished in the water

(Sweeney 1992). Due to the amount of handling the dolphins received additional to the biopsies, it was impossible to interpret behavioral reactions to the biopsies alone.

DORSAL FIN NOTCHES

Our data indicate that a dolphin's notching pattern may change over time. While this conclusion should come as no surprise to others applying similar methods of photo-identification (notch accumulation over time by individuals has been mentioned by Scott *et al.* [1990] and Würsig and Harris [1990]), it would be imprecise to conclude from our data that all dolphins are born with no notches and steadily accumulate them throughout life. These data represent a "snapshot" of 36 different dolphins, not a longitudinal study. Male dolphins could, for instance, accumulate the majority of their notches as juveniles, while assimilating themselves into the social system. The tendency for female dolphins to have more notches with increasing numbers of female affiliates implies that some notching may occur as a result of social interactions.

CONCLUSIONS

The Texas coast, spanning 2.5° latitude, with its unique cycling of tropical and temperate conditions and sparse coastal beaches punctuated by productive estuaries, presents an interesting yet little understood blend of bottlenose dolphin life history patterns. Bottlenose dolphins on the Texas coast have movement and social patterns similar to those of other coastal bottlenose dolphins, yet the patterns are not simply a duplication of findings from other, better understood study sites.

With respect to mass mortalities, the Matagorda Bay dolphin population seems to be physically healthy (Sweeney 1992) and numerically robust, occupying all surveyed regions of the bay. The resident dolphins are probably susceptible to local anthropogenic and naturally occurring toxins. Post-1992 die-off population numbers appear not to have changed from earlier estimates (Gruber 1981). However, statistical power to detect a decrease in numbers between this and previous studies is probably low, given the erratic survey effort and large confidence intervals. The handful of examples of travel between Texas bays, in spite of the low level monitoring effort which produced the observations, suggests to us that an individual Texas bay ecosystem could recover numerically from localized dolphin mortalities. These regional, within bay, dolphin populations do not appear to be truly isolated.

These conclusions must be considered tentative, however. Despite the indicated non-isolated nature of the population, nothing is yet known about interactions between the apparently resident dolphins and the visitors, and it is not known if the dolphins which died in spring 1992 were resident. If the resident dolphins seldom mate with visitors, loss of all or most residents in an area could have significant impact on the genetic (and perhaps cultural) makeup of dolphins in the area regardless of numeric recovery. This study raises several questions: Are there separate inshore/resident and coastal/transient bottlenose dolphin stocks on the Texas coast? If so, is there genetic exchange? What sociobiological factors drive the two lifestyles, and would an otherwise non-resident dolphin take up residency in a depleted bay?

The major ambiguities of population extent and size, social and behavioral patterns, and characterizations of within-bay *vs.* gulf-coast dolphins can only be answered by further work. We recommend: (1) continued visual and photographic survey efforts, on a monthly basis, to catalogue and reliably re-identify not only human-marked but naturally identifiable dolphins throughout this and other Texas bay systems and along the Texas gulf coast; (2) an intensive genetic study along the entire Texas coast, to coordinate with the ongoing MMRP photo-identification work in the bay systems of Galveston, Matagorda, Corpus Christi, and South Padre Island; and (3) at least two more intensive NMFS-led physiology/radio-tracking efforts to recapture some of the same dolphins for physiology and toxin level follow-up. The second point is especially necessary for proper description of population discreteness and size(s), and evaluation of the effects of mass mortalities. The third recommendation will provide further data on sex and age distributions, necessary for a fuller understanding of the sociobiology of dolphins on the Texas coast.

LITERATURE CITED

Acevedo-Gutiérrez, A. 1989. Uso del área por el tursión (*Tursiops truncatus*) en La Ensenada de La Paz, durante el verano de 1987. Tesis de Licenciatura, Universidad Autónome de Baja California Sur, La Paz, México. 115 pp.

Asper, E. D. 1975. Techniques of live capture of smaller cetacea. Journal of the Fisheries Research Board of Canada 32:1191–1196.

Ballance, L. T. 1990. Residence patterns, group organization, and surfacing associations of bottle dolphins in Kino Bay, Gulf of California, Mexico. Pages 267–283 *in* S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. Academic Press, San Diego, CA.

Ballance, L. T. 1992. Habitat use patterns and ranges of the bottlenose dolphin in the Gulf of California, Mexico. Marine Mammal Science 8:262–274.

Batschelet, E. 1972. Recent statistical methods for orientation data. Pages 61–91 *in* S. R. Galler, K. Schmidt-Koenig, G. J. Jacobs, and R. E. Belleville, eds. Animal Orientation and Navigation. NASA, Washington, DC.

Bearzi, G., and G. Notarbartolo di Sciara. 1993. Dolphin project: A bottlenose dolphin research and conservation program in the Northern Adriatic Sea. Tethys Research Institute Technical Report TRI/DP 93-02. 13 pp.

Bel'kovich, V. M. 1991. Herd structure, hunting, and play: Bottlenose dolphins in the Black Sea. Pages 17–38 *in* K. Pryor and K. S. Norris, eds. Dolphin Societies – Discoveries and Puzzles. University of California Press, Berkeley, CA.

Blower, J. G., L. M. Cook, and J. A. Bishop. 1981. Estimating the Size of Animal Populations. George Allen and Unwin Ltd. London, England. 128 pp.

Bräger, S. 1992. Untersuchungen zur Ortstreue und zum Vergesellschaftungsmuster des Großen Tümmlers, *Tursiops truncatus* (Montagu, 1821). Diplomarbeit. Christian-Albrechts Universität zu Kiel, Germany. 97 pp.

Bräger, S. 1993. Diurnal and seasonal behavior patterns of bottlenose dolphins (*Tursiops truncatus*). Marine Mammal Science 9:434–438.

Bräger, S., B. Würsig, A. Acevedo, and T. Henningsen. 1994. Association patterns of bottlenose dolphins (*Tursiops truncatus*) in Galveston Bay, Texas. Journal of Mammalogy 75:431–437.

BrainPower. 1986. StatView 4.0. BrainPower, Inc., Calabasas, CA.

Bruce-Allen, L. J., and J. R. Geraci. 1985. Wound healing in the bottlenose dolphin (*Tursiops truncatus*). Canadian Journal of Fisheries and Aquatic Science 42:21–44.

Cairns, S. J., and S. J. Schwager. 1987. A comparison of association indices. Animal Behaviour 35:1454–1469.

Caldwell, D. K., and M. C. Caldwell. 1972. The World of the Bottlenose Dolphin. J. B. Lippincott Co., Philadelphia, PA. 157 pp.

Caldwell, Mj., R. H. Defran, D. W. Weller, and A. Sandoval. 1991. A southern home range boundary for Pacific coast bottlenose dolphins in the southern California bight. Page 12 *in* Abstracts of the Ninth Biennial Conference on the Biology of Marine Mammals. 5–9 December, Chicago, IL.

Connor, R. C., R. A. Smolker, and A. F. Richards. 1992. Two levels of alliance formation among male bottlenose dolphins (*Tursiops* sp.). Proceedings of the National Academy of Sciences 89:987–990.

Curran, S., B. Wilson, P. M. Thompson, and P. S. Hammond. 1993. An ecological study of a community of bottlenose dolphins in the Moray Firth, N. E. Scotland. Page 39 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Defran, R. H., and D. W. Weller. 1993. Range characteristics of Pacific coast bottlenose dolphins. Page 41 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Defran, R. H., and D. W. Weller. In press. The occurrence, distribution, and site fidelity of bottlenose dolphins (*Tursiops truncatus*) in San Diego, California. Marine Mammal Science.

Defran, R. H., D. W. Weller, D. Kelly, and M. A. Espinoza. In press. Range characteristics of Pacific coast bottlenose dolphins within the southern California bight. Marine Mammal Science.

Delgado, A. 1991. Algunos aspectos de la ecología de poblaciones de las toninas (*Tursiops truncatus* Montagu, 1821) en La Laguna de Términos y Sonda de Campeche, México. Tesis de Licenciatura. ENEP Iztacala, Universidad Nacional Autónoma de México, Ciudad de México. 148 pp.

Deneba. 1992. Canvas 3.5. Deneba Software, Miami, FL.

Dice, L. R. 1945. Amount of ecological association between species. Ecology 26:297-302.

dos Santos, M. E., and M. Lacerda. 1987. Preliminary observations of the bottlenose dolphin (*Tursiops truncatus*) in the Sado estuary (Portugal). Aquatic Mammals 13:65–80.

Eberhardt, L. L., D. G. Chapman, and J. R. Gilbert. 1979. A review of marine mammal census methods. Wildlife Monographs 63:4–46.

Essapian, F. S. 1962. An albino bottle-nosed dolphin, *Tursiops truncatus*, captured in the United States. Norsk Hvalfangst-Tidende 51:341–344.

Evans, W. E. 1971. Orientation behavior of delphinids: Radiotelemetric studies. Annals of the New York Academy of Sciences 188:142–160.

Fernandez, S. P. 1992. Composición de edad y sexo parámetros del ciclo de vida de toninas (*Tursiops truncatus*) varadas en el noroeste del Golfo de México. Tesis de Maestría. Instituto Tecnológico y de Estudios Superiores de Monterrey, Guaymas, México. 109 pp.

Fertl, D. C. 1993. Occurrence and behavior of bottlenose dolphins (*Tursiops truncatus*) in association with the shrimp fishery in Galveston Bay, Texas. Page 48 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Fertl, D. C. 1994. Occurrence, movements, and behavior of bottlenose dolphins (*Tursiops truncatus*) in association with the shrimp fishery in Galveston Bay, Texas. M.Sc. thesis. Texas A&M University, College Station. 117 pp.

Gruber, J. A. 1981. Ecology of the Atlantic bottlenosed dolphin (*Tursiops truncatus*) in the Pass Cavallo area of Matagorda Bay, Texas. M.Sc. thesis. Texas A&M University, College Station. 182 pp.

Hammond, P. S. 1986. Estimating the size of naturally marked whale populations using capture-recapture techniques. Pages 253–282 *in* G. P. Donovan, ed. Behavior of Whales in Relation to Management. Reports of the International Whaling Commission (Special Issue 8). IWC, Cambridge, England.

Hansen, L. J. 1983. Population biology of the coastal bottlenose dolphin (*Tursiops truncatus*) of southern California. M.A. thesis. California State University, Sacramento. 103 pp.

Hansen, L. J. 1990. California coastal bottlenose dolphins. Pages 403–419 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Hanson, M. T., and R. H. Defran. 1989. The behavior and ecology of the Pacific coast bottlenose dolphin. Page 26 *in* Abstracts of the Eighth Biennial Conference on the Biology of Marine Mammals. 7–11 December, Pacific Grove, CA

Harzen, S. 1989. Zum Vorkommen und zur raum-zeitlichen Aktivität des Großen Tümmlers, *Tursiops truncatus* (Montagu, 1821) im Mündungsgebiet des Sado, Portugal. Diplomarbeit. Universität Bielefeld, Germany. 99 pp.

Heimlich-Boran, J. R. 1993. Social organisation of the short-finned pilot whale, *Globicephala macrorhynchus*, with special reference to the comparative social ecology of delphinids. Ph.D. dissertation. University of Cambridge, England. 134 pp.

Heimlich-Boran, S. L. 1986. Cohesive relationships among Puget Sound killer whales. Pages 251–284 *in* B. C. Kirkevold and J. S. Lockard, eds. Behavioral Biology of Killer Whales. Alan R. Liss, Inc., New York, NY.

Irvine, A. B., M. D. Scott, R. S. Wells, and J. H. Kaufmann. 1981. Movements and activities of the Atlantic bottlenose dolphin, *Tursiops truncatus*, near Sarasota, Florida. Fishery Bulletin 79:671–688.

Jones III, S. C. 1988. Survey of the Atlantic bottlenose dolphin (*Tursiops truncatus*) population near Galveston, Texas. M.Sc. thesis. Texas A&M University, College Station. 52 pp.

Jones III, S. C. 1991. Movements of bottlenose dolphins between inlets along the Texas coast. Page 37 *in* Abstracts of the 9th Biennial Conference on the Biology of Marine Mammals. 7–11 November, Chicago, IL.

Kenney, R. D. 1990. Bottlenose dolphins off the northeastern United States. Pages 369–386 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Mallon-Day, R. S. 1993. Bottlenose dolphins (*Tursiops truncatus*) off of Cape May County, New Jersey. Page 72 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

McHugh, M. B. 1989. Population numbers and feeding behavior of the Atlantic bottlenose dolphin (*Tursiops truncatus*) near Aransas Pass, Texas. M.A. thesis. University of Texas, Austin. 97 pp.

Mead, J. G., and C. W. Potter. 1990. Natural history of bottlenose dolphins along the central Atlantic coast of the United States. Pages 165–195 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Mech, L. D. 1983. Handbook of Animal Radio-Tracking. University of Minnesota Press, Minneapolis, MN. 107 pp.

Microsoft. 1992. Excel 4.0. Microsoft Corporation, Redmond, WA.

Norris, K. S., B. Würsig, R. S. Wells, M. Würsig, S. M. Brownlee, C. Johnson, and J. Solow. 1985. The behavior of the Hawaiian spinner dolphin, *Stenella longirostris*. NMFS Adm. Rep. #LJ-85-06C, SWFC, P. O. Box 271, La Jolla, CA 92038. 213 pp.

Norris, K. S., B. Würsig, R. S. Wells, M. Würsig, S. M. Brownlee, C. Johnson, and J. Solow. 1994. The Hawaiian Spinner Dolphin. University of California Press, Berkeley, CA. 408 pp.

Odell, D. K., and E. D. Asper. 1990. Distribution and movements of freeze branded bottlenose dolphins in the Indian and Banana Rivers, Florida. Pages 515–540 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Orlando, S. P. Jr., L. P. Rozas, G. H. Ward, and C. J. Klein. 1993. Salinity characteristics of Gulf of Mexico esturaries. National Oceanic and Atmospheric Administration, Office of Ocean Resources Conservation and Assessment, Silver Spring, MD. 209 pp.

Peddemors, V. 1989. An assessment of factors influencing bottlenose dolphin capture in shark gill nets off Natal, South Africa. Page 49 *in* Abstracts of the Eighth Biennial Conference on the Biology of Marine Mammals. 7–11 December, Pacific Grove, CA.

Price-May, L. 1993. The use of a geographical information system to correlate dolphin home range with environmental factors. Page 88 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Rossbach, K. A., B. R. Mate, S. L. Nieukirk, and R. S. Wells. 1993. Satellite-monitored movements and dive behavior of a bottlenose dolphin (*Tursiops truncatus*) in Tampa Bay, Florida: A pilot study. Page 93 *in* Abstracts of the 10th Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Rudin, M., A. Spellman, and J. G. Morris. 1991. Distribution, group composition, behavior and abundance of bottlenose dolphin, *Tursiops truncatus*, based on photoidentification in the Indian River Lagoon, Florida. Page 60 *in* Abstracts of the Ninth Biennial Conference on the Biology of Marine Mammals. 5–9 December, Chicago, IL.

Scott, J. A., D. M. Feinholz, and R. H. Defran. 1993. Northern range limits of Pacific coast bottlenose dolphins (*Tursiops truncatus*) in California. Page 97 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Scott, M. D., R. S. Wells, and A. B. Irvine. 1990a. A long-term study of bottlenose dolphins on the west coast of Florida. Pages 235–244 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Scott, M. D., R. S. Wells, A. B. Irvine, and B. R. Mate. 1990b. Tagging and marking studies on small cetaceans. Pages 489–514 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Seber, G. A. F. 1982. The Estimation of Animal Abundance and Related Parameters. Charles Griffin and Company, Ltd. London, England. 654 pp.

Shane, S. H. 1977. Population biology of the Atlantic bottlenose dolphin, *Tursiops truncatus*, in the Aransas Pass area of Texas. M.Sc. thesis. Texas A&M University, College Station. 239 pp.

Shane, S. H. 1990. The behavior and ecology of the bottlenose dolphin at Sanibel Island, Florida. Pages 245–265 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Smolker, R. A., A. F. Richards, R. C. Connor, and J. W. Pepper. 1992. Sex differences in patterns of association among Indian Ocean bottlenose dolphins. Behaviour 123:38–69.

Sweeney, J.C. 1992. Veterinary assessment report, *Tursiops truncatus*, Matagorda Bay, Texas, July, 1992. NMFS-SEFSC Contribution MIA-92/93-41. National Marine Fisheries Service, 75 Virginia Beach Dr., Miami, FL.

Swingle, W. M., S. G. Barco, and W. A. McLellan. 1993. Characterizing a migratory population of coastal bottlenose dolphins (*Tursiops truncatus*) in Virginia. Page 105 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

TMMSN. 1992. Unpublished necropsy report for dolphin ID #PO249 (authored by D. Cowan, M.D.). Texas Marine Mammal Stranding Network. 4700 Ave. U, Bldg. 303, Galveston, TX 77551. 5 pp.

Urian, K. W., R. S. Wells, A. J. Read, D. A. Duffield, and D. D. Shell. 1993. Seasonality of reproduction in bottlenose dolphins. Page 108 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Waples, D. M., R. S. Wells, B. M. Allen, D. P. Costa, and G. A. J. Worthy. 1993. Habitat utilization by bottlenose dolphins in Sarasota Bay, Florida. Page 110 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Weller, D. W. 1991. The social ecology of Pacific coast bottlenose dolphins. M.S. thesis. San Diego State University, CA. 93 pp.

Wells, R. S. 1991. The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pages 199–226 *in* K. Pryor and K. S. Norris, eds. Dolphin Societies – Discoveries and Puzzles. University of California Press, Berkeley, CA.

Wells, R. S., M. D. Scott, and A. B. Irvine. 1987. The social structure of free-ranging bottlenose dolphins. Pages 247–305 *in* H. H. Genoways, ed. Current Mammalogy, vol. 1. Plenum Press, New York, NY.

Wells, R. S., L. J. Hansen, A. Baldridge, T. P. Dohl, D. L. Kelly, and R. H. Defran. 1990. Northward extension of the range of bottlenose dolphins along the California coast. Pages 421–431 *in* S. Leatherwood and R. R. Reeves, eds. The Bottlenose Dolphin. Academic Press, San Diego, CA.

Wells, R. S., K .W. Urian, A. J. Read, M. K. Bassos, and W. J. Carr. 1993. Community stucture of bottlenose dolphins along the central west coast of Florida. Page 112 *in* Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals. 11–15 November, Galveston, TX.

Würsig, B. 1978. Occurrence and group organization of Atlantic bottlenose porpoises (*Tursiops truncatus*) in an Argentine bay. Biological Bulletin 154:348–359.

Würsig, B. 1982. Radio tracking dusky porpoises in the south Atlantic. *In* Mammals in the Seas, FAO Fish. Ser. #5, vol. IV.

Würsig, B., and T. A. Jefferson. 1990. Methods of photo-identification for small cetaceans. Pages 43–52 *in* P. S. Hammond, S. A. Mizroch, and G. P. Donovan, eds. Individual Recognition of Cetaceans: Use of Photo-identification and Other Techniques to Estimate Population Parameters. Report of the International Whaling Commission (Special Issue 12). IWC, Cambridge, England.

Würsig, B., and G. Harris. 1990. Site and association fidelity in bottlenose dolphins off argentina. Pages 361-365 in S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. Academic Press, San Diego, CA.

Würsig, B., and M. Würsig. 1977. The photographic determination of group size, composition, and stability of coastal porpoises (*Tursiops truncatus*). Science 198:755–756.

Würsig, B., and M. Würsig. 1979. Behavior and ecology of the bottlenose dolphin, *Tursiops truncatus*, in the south Atlantic. Fishery Bulletin 77:399–412.

Würsig, B., and M. Würsig. 1980. Behavior and ecology of the dusky dolphin, *Lagenorhychus obscurus*, in the South Atlantic. Fishery Bulletin 77:871–890.

Würsig, B., F. Cipriano, and M. Würsig. 1991. Dolphin movement patterns – information from radio and theodolite tracking studies. Pages 79–111 *in* K. Pryor and K. S. Norris, eds. Dolphin Societies – Discoveries and Puzzles. University of California Press, Berkeley, CA.

Zar, J. H. 1984. Biostatistical Analysis, 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 pp.

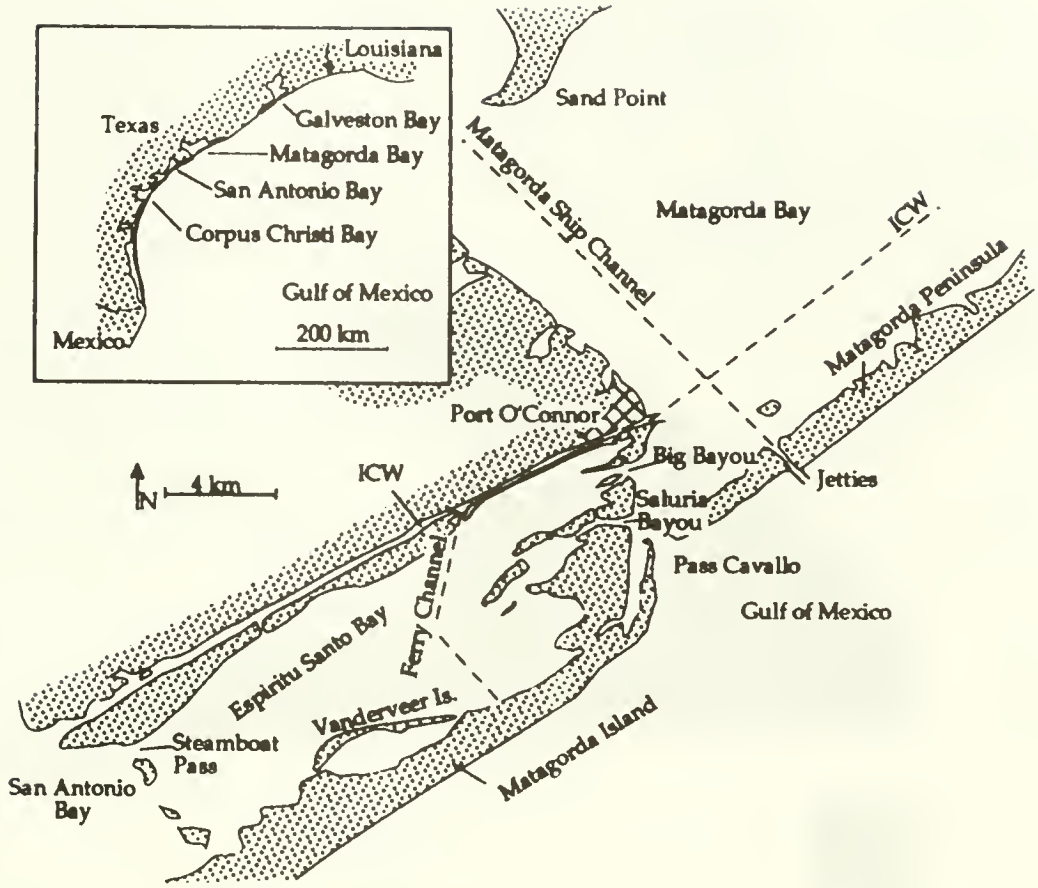


Figure 1. Map of the Port O'Connor area of Matagorda Bay.

a.

b.

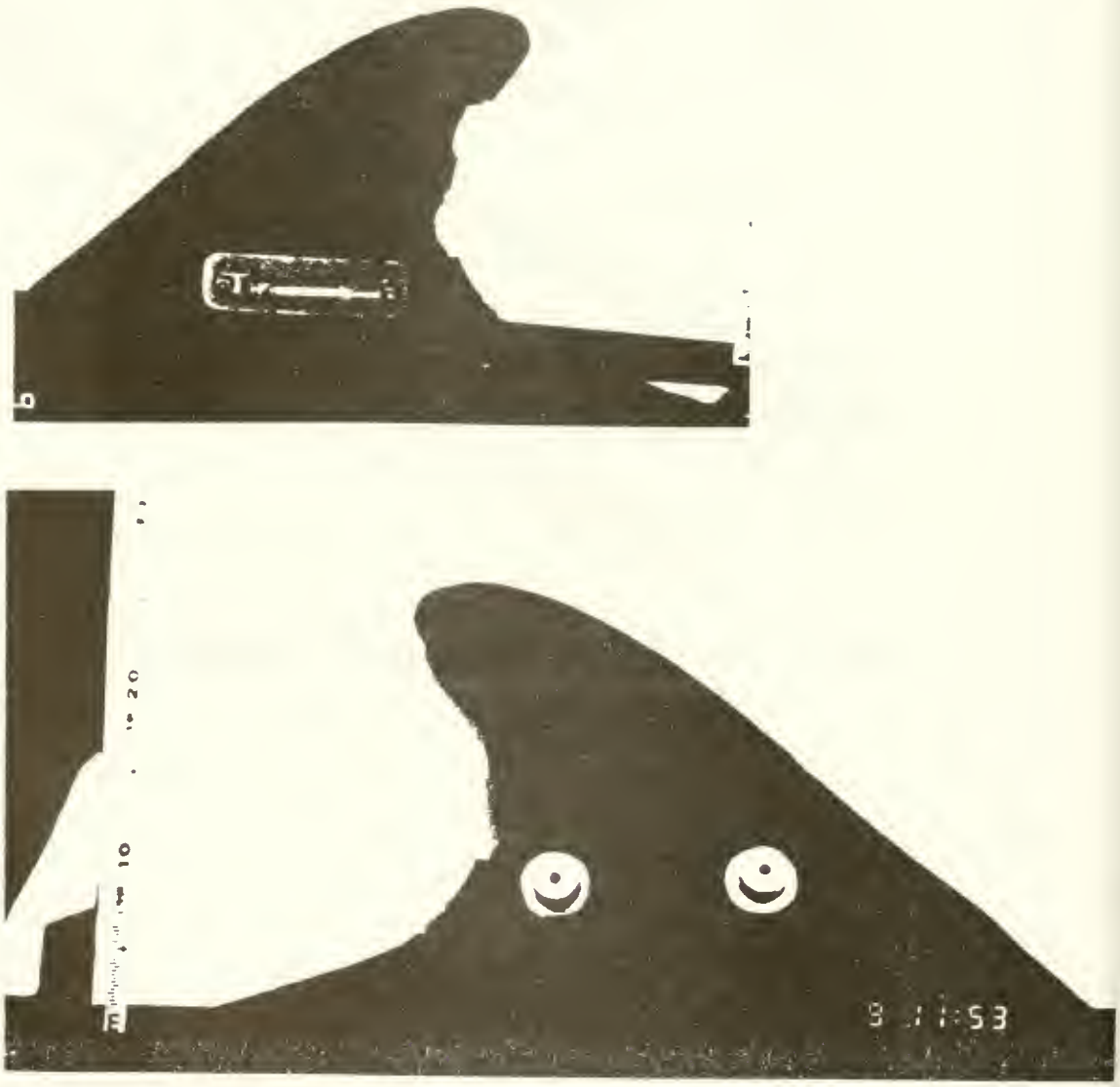


Figure 2. Left and right sides of a dolphin dorsal fin (FB502) showing radio package placement (a) and magnesium nuts (b).

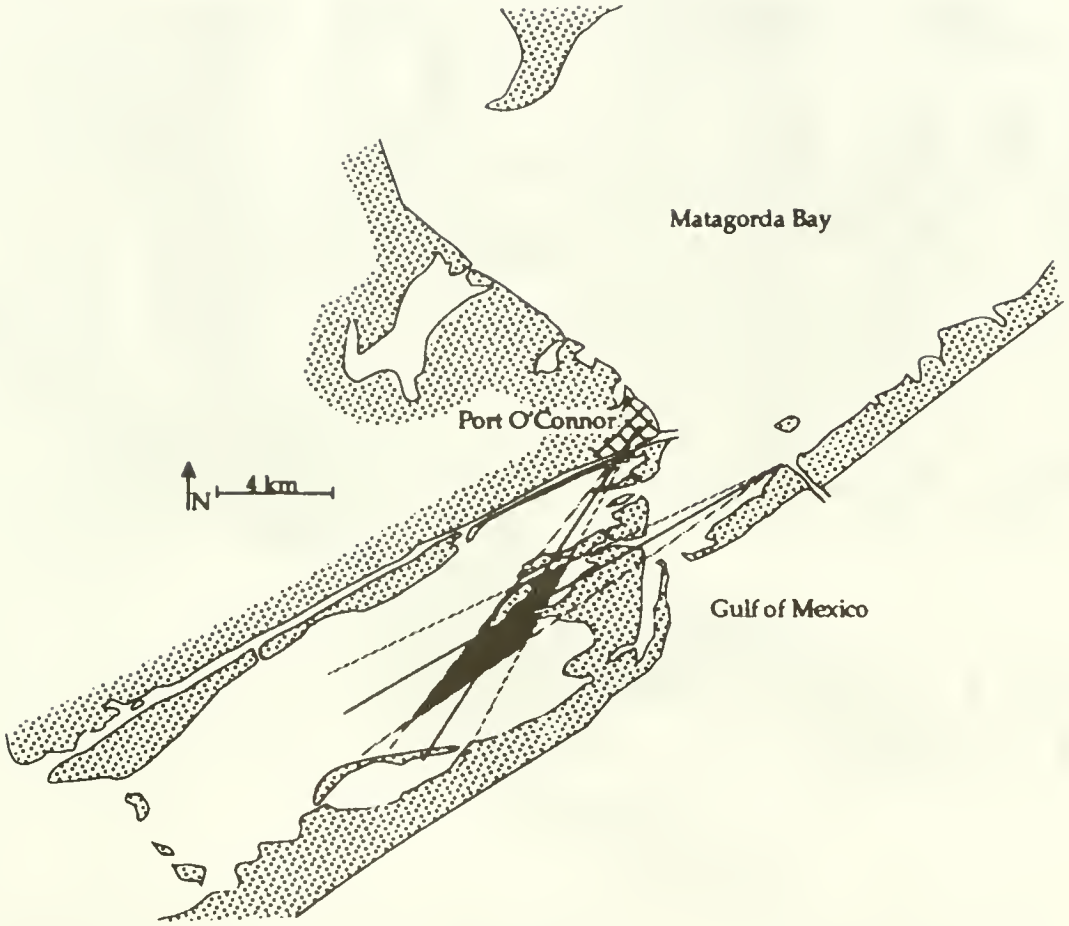


Figure 3. Example triangulation for FB518 at 1045 hr, 11 August 1992, from Home Base, in Port O'Connor, and a tracking vessel at the base of the western Matagorda Ship Channel jetty. Shaded region indicates the error polygon associated with the position of the dolphin. A ± 5° error range is indicated for five-element antennas.

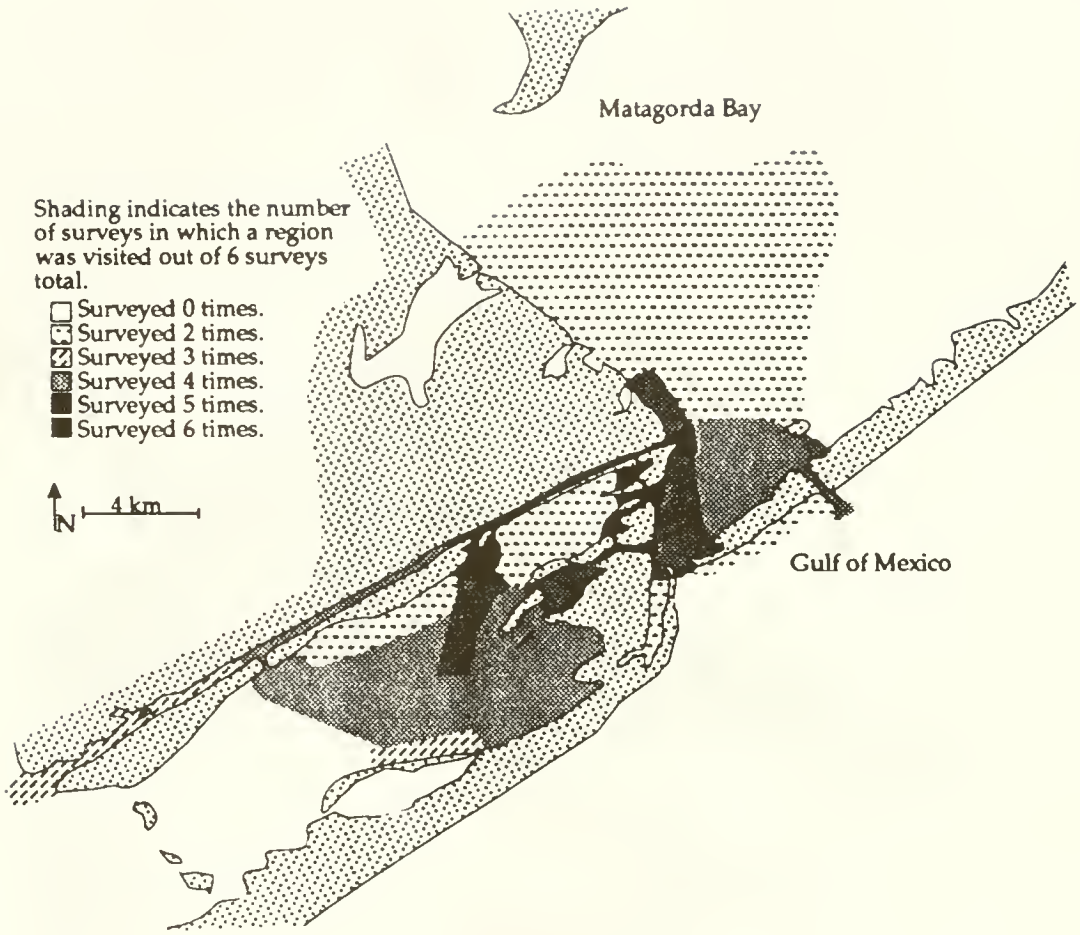


Figure 4. Photographic survey effort, May 1992–June 1993. Surveys from July 1992–September 1992 are excluded because they are biased for radio tracking. The May 1993 survey is excluded because it ended early due to inclement weather.

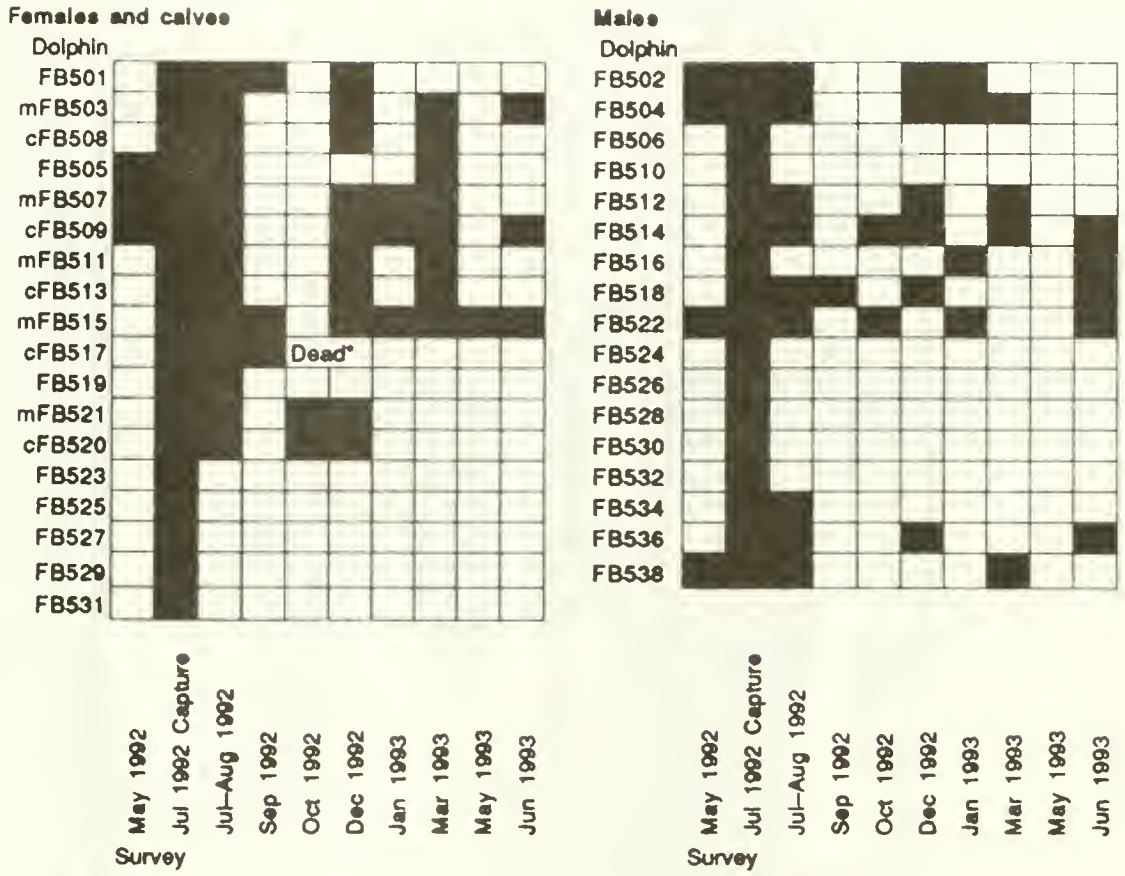


Figure 5. Sightings of freeze-branded dolphins across surveys. "m" and "c" denote mother-calf pairs.
* FB517, calf of FB515, was found dead on 13 September 1992. Necropsy showed that it died from an intestinal infarction unrelated to capture or tagging stress (TMMSN 1992).

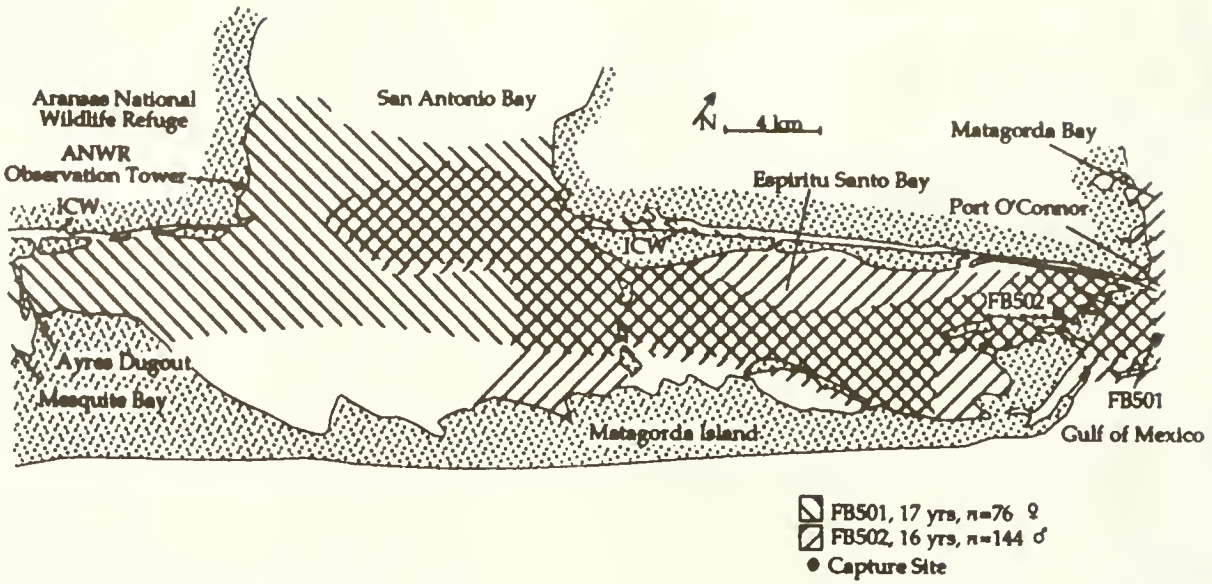


Figure 6a. Summary ranges for radio tagged dolphins FB501 and FB502, from radio telemetry and sightings, May 1992–June 1993, with information on age and sex. "*n*" refers to the number of positions used to determine the ranges.

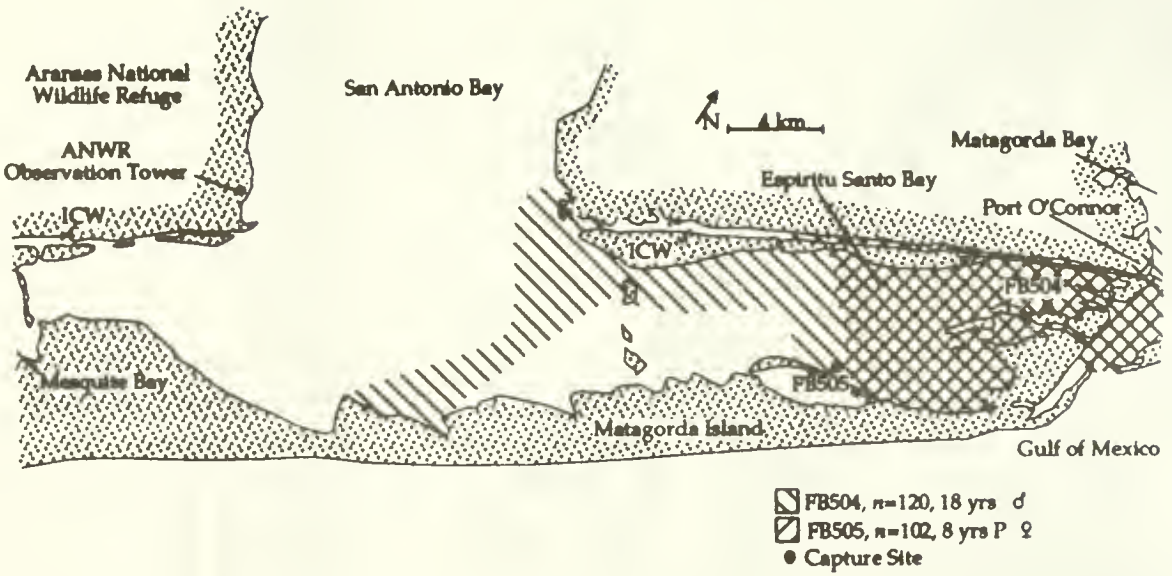


Figure 6b. Summary ranges for radio tagged dolphins FB504 and FB505, from radio telemetry and sightings, May 1992–June 1993, with information on age and sex. "P" denotes a pregnant dolphin. "*n*" refers to the number of positions used to determine the ranges.

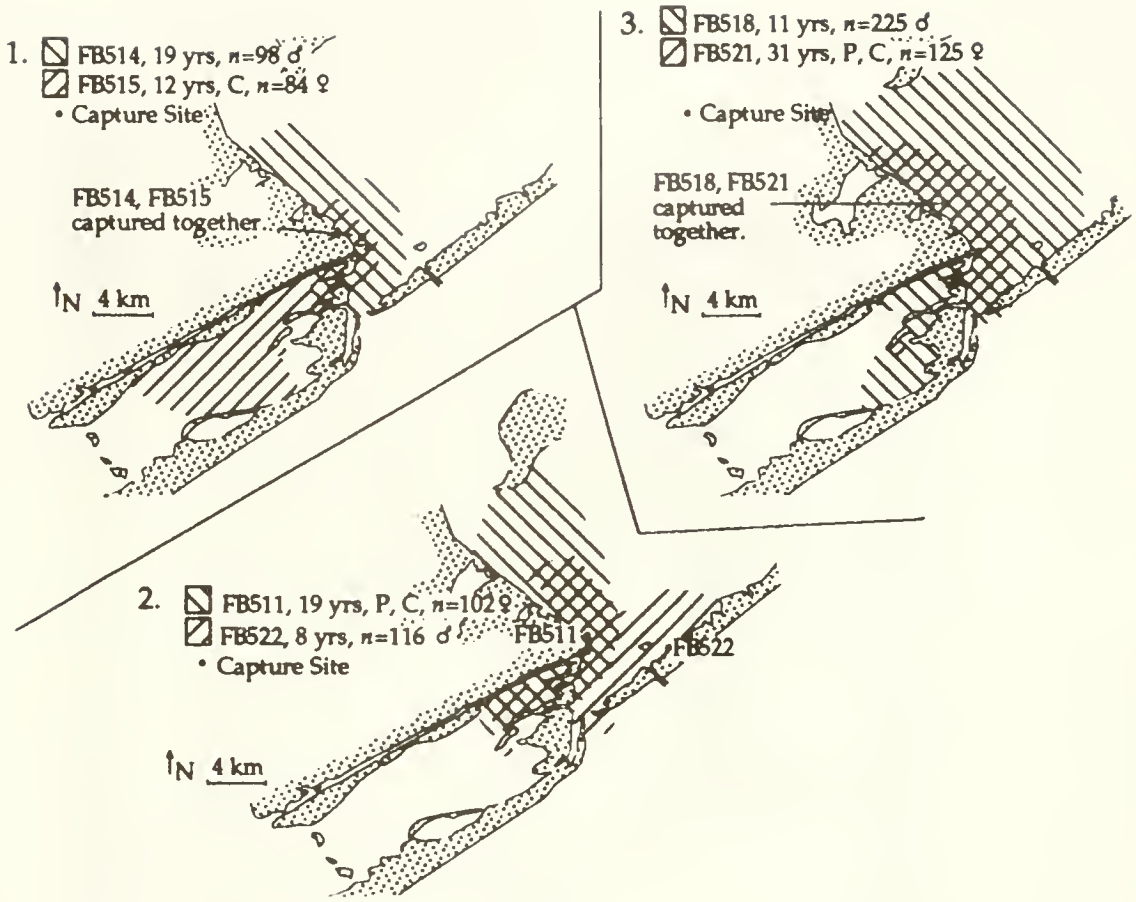


Figure 6c. Summary ranges for radio tagged dolphins FB514 and FB515 (1), FB511 and FB522 (2), and FB518 and FB521 (3), from radio telemetry and sightings, May 1992–June 1993, with information on age and sex. "P" denotes a pregnant animal, "C" denotes "with calf". "*n*" refers to the number of positions used to determine the ranges.

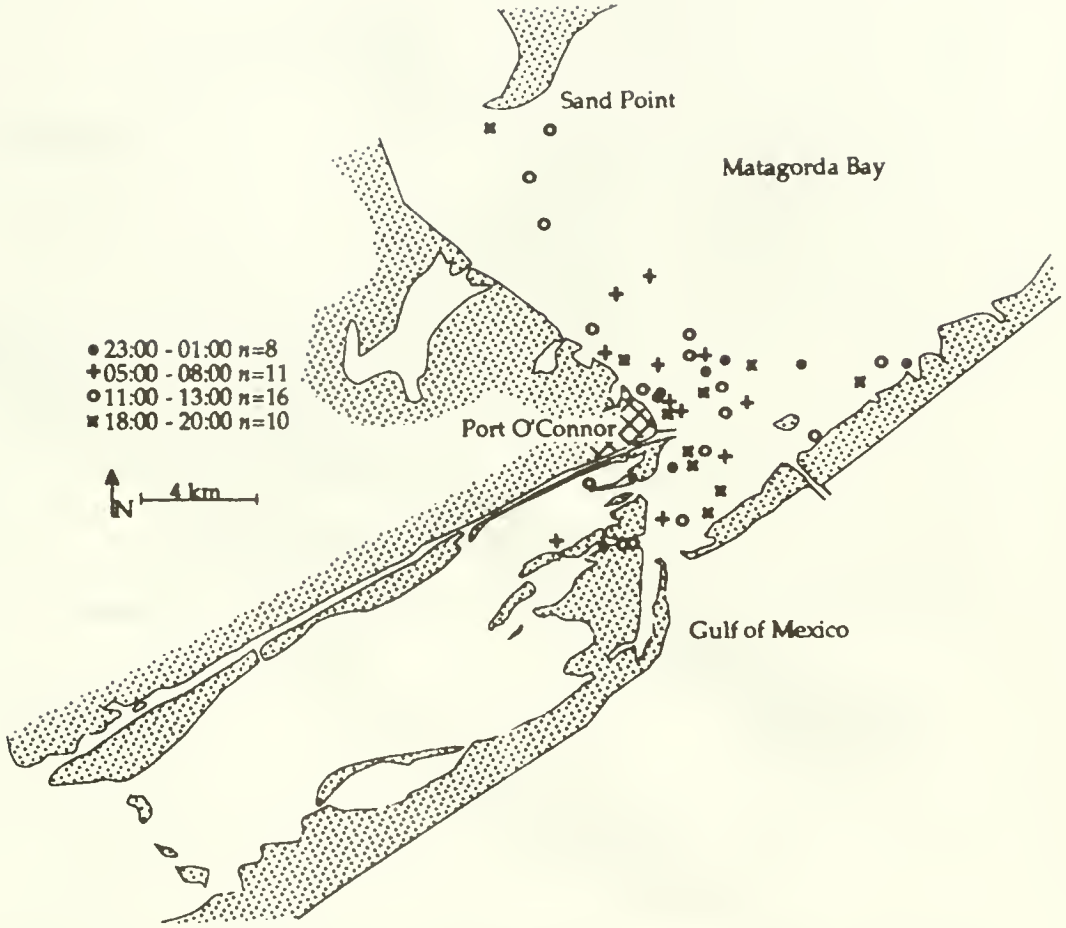


Figure 7. Positions of FB518 by time of day, 15 June 1992–13 September 1992, from radio telemetry and sightings.

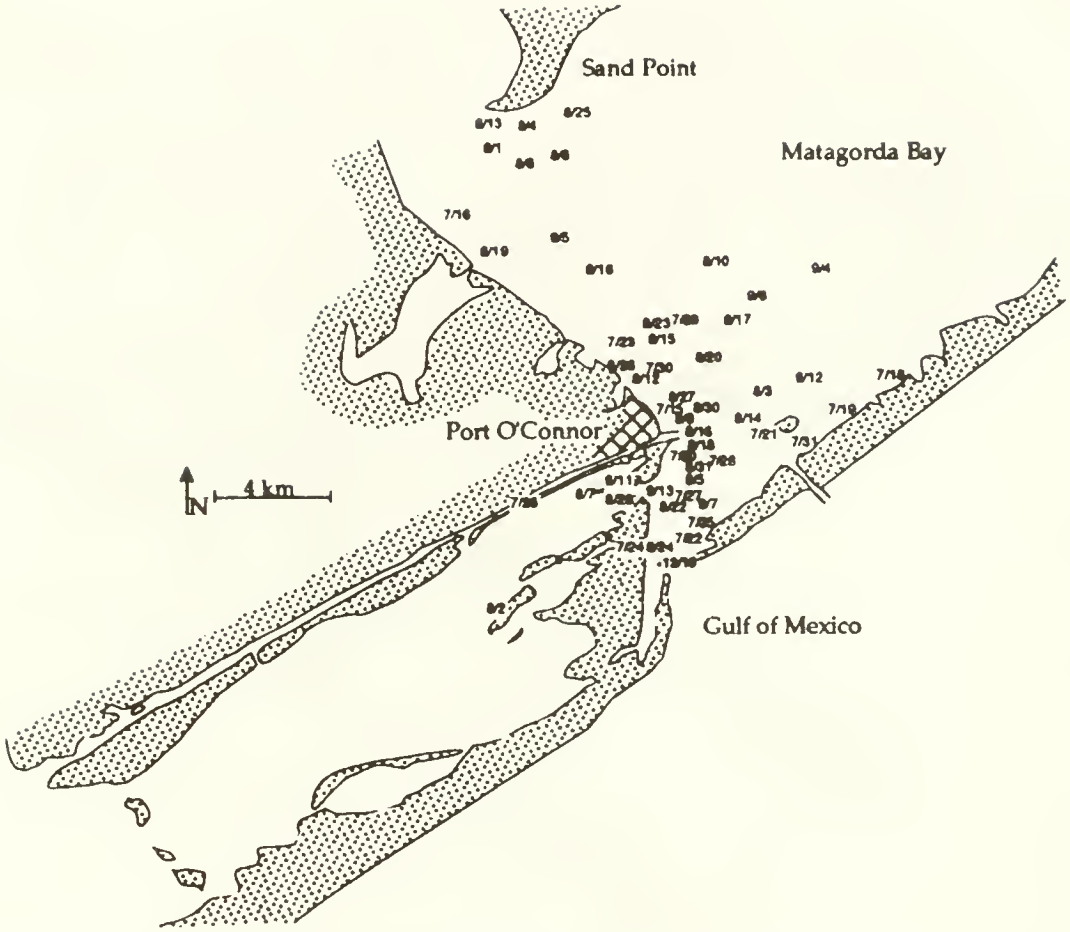


Figure 8. Approximate noon positions for dolphin FB518, 15 June 1992–13 September 1992, from radio tracking and sightings (two subsequent sightings in bold). "*n*" = 53 positions.

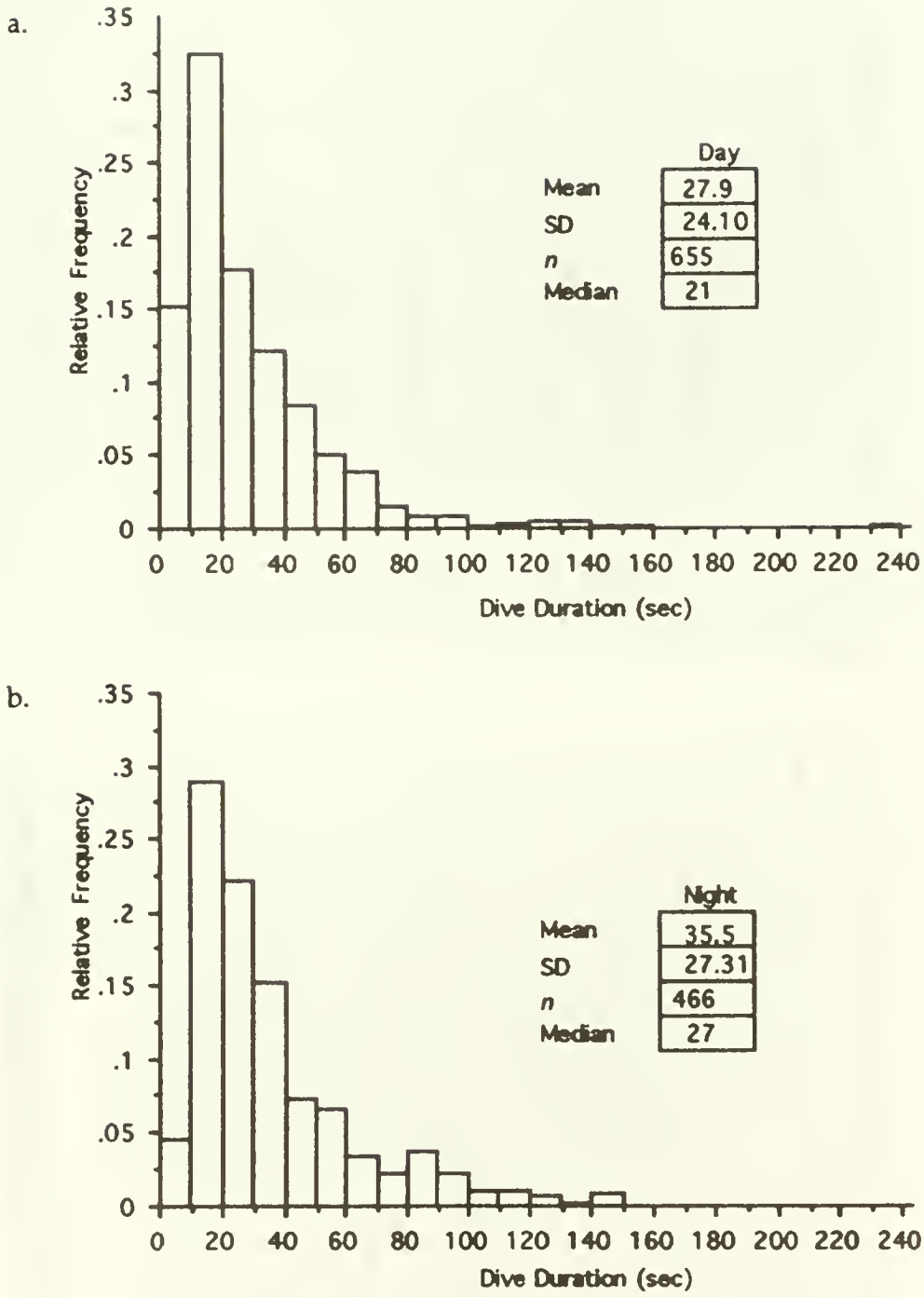


Figure 9. Relative frequency histograms of dive durations during day (a) and night (b). Data are composed of concatonated 30-min samples, selected at random, one from each dolphin. "*n*" refers to the number of individual surfacings, and is not a reference to any averaged 30-min sample.

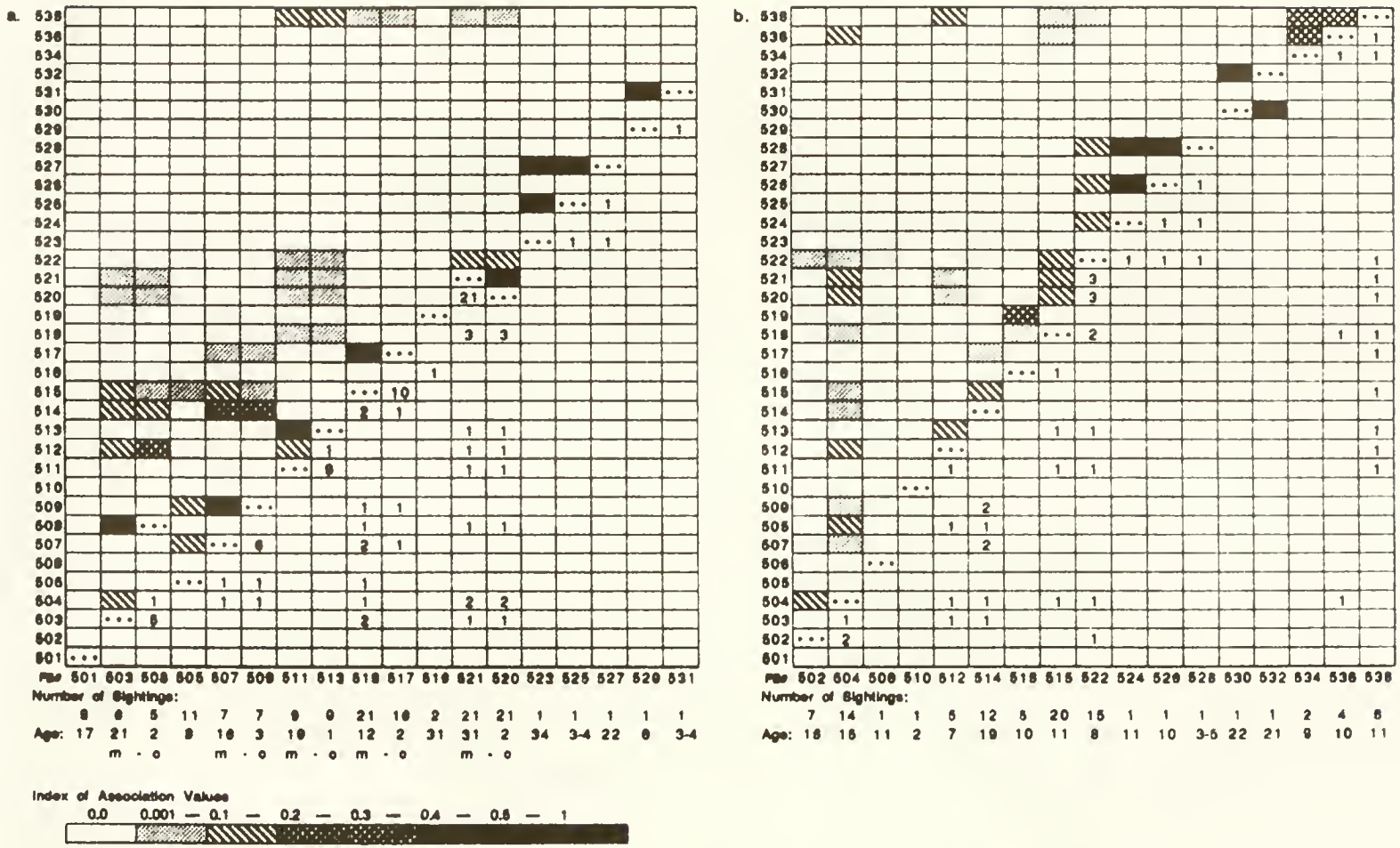
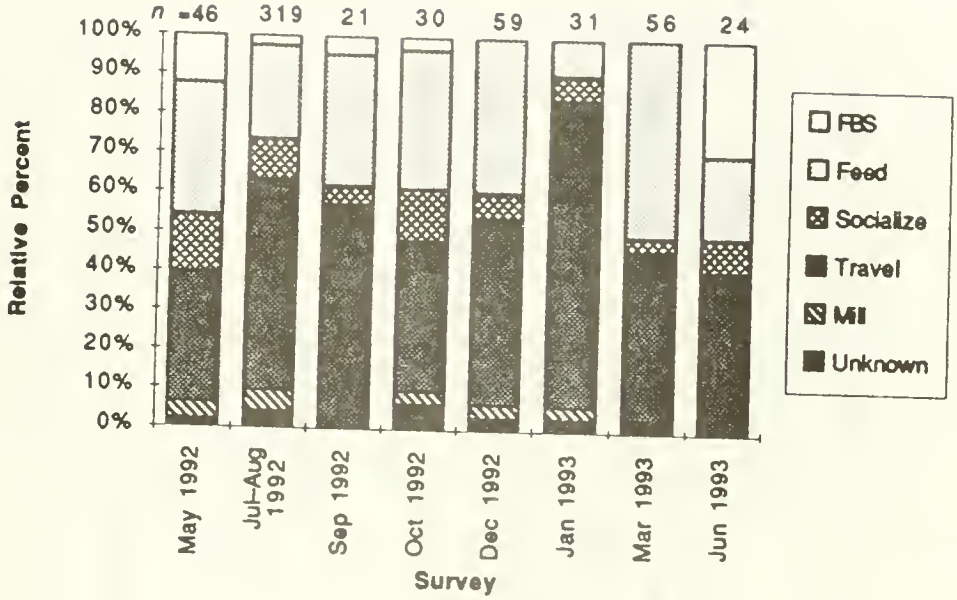


Figure 10. Affiliations of all female and calf (a) and male (b) freeze-branded dolphins (as measured by dolphins occurring in the same group in a sighting), May 1992–June 1993. Shaded regions correspond to the half-weight index of association values. Values in cells correspond to the number of times a dolphin in a given row occurred in the same group as a dolphin in a given column. "m - " and "c" denote mothers and their calves.

a.



b.

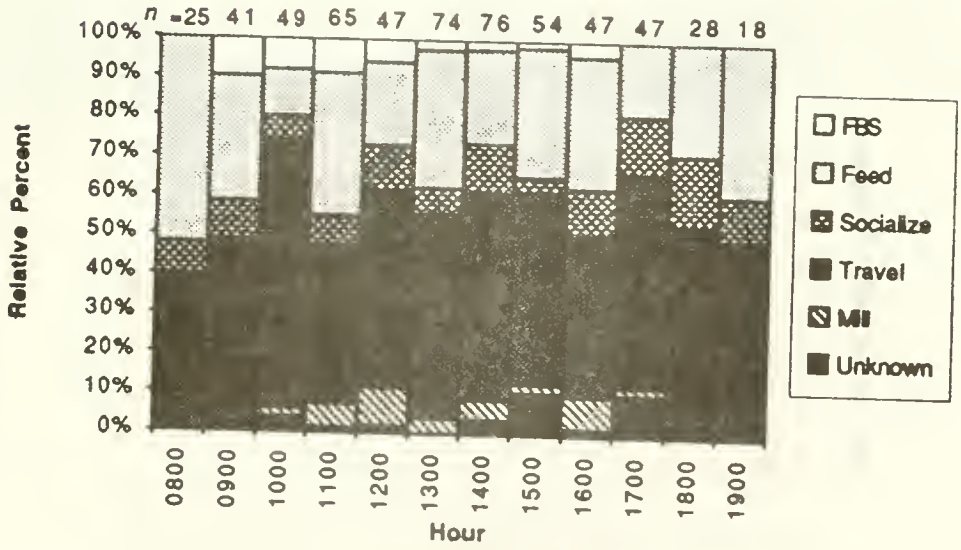


Figure 11. Plots of relative percents of behaviors by survey (a) and hour of day (b). The May 1993 survey is excluded.

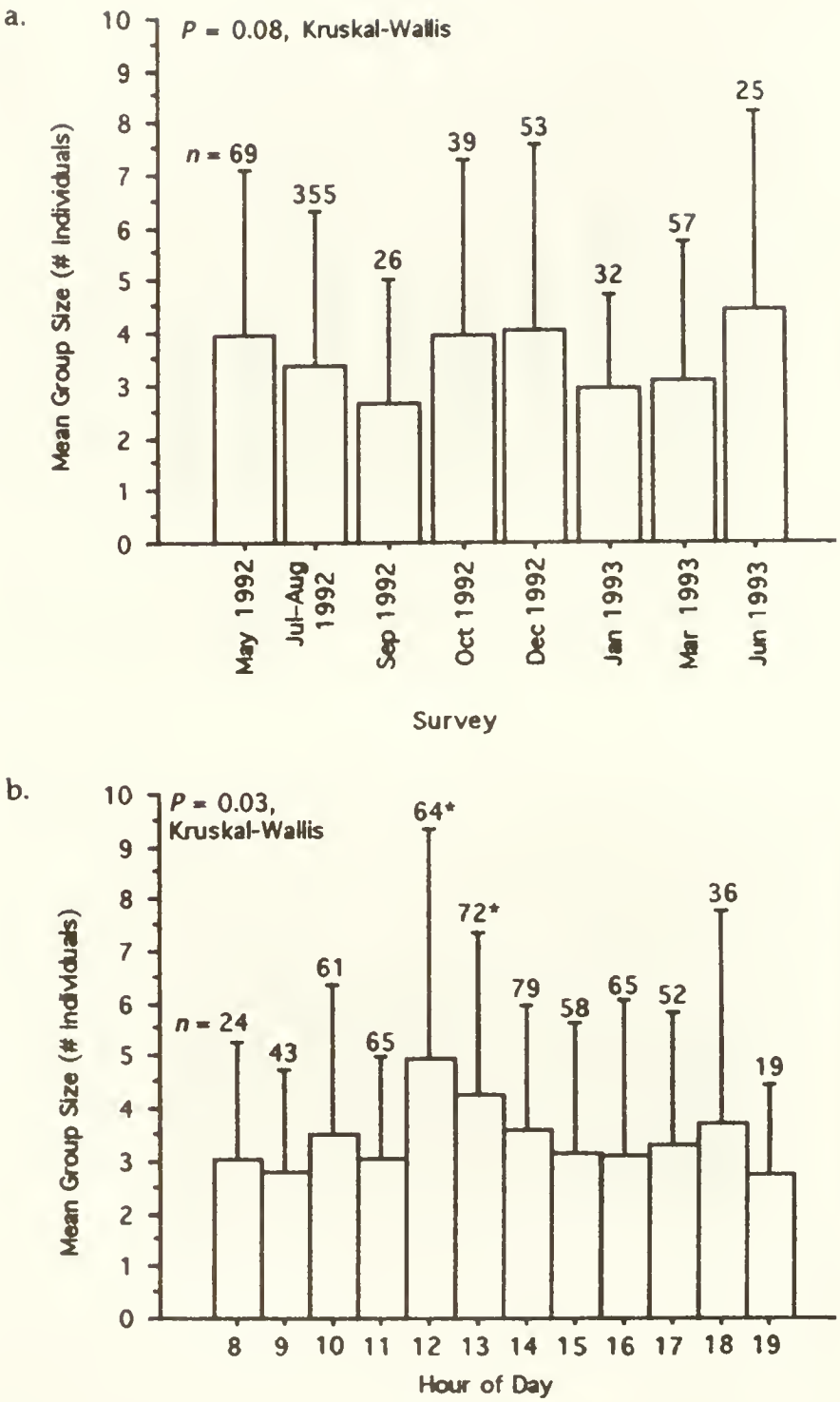


Figure 12. Mean group sizes by survey (a) and hour (b), error bars indicate 1 SD. Group sizes from 1200–1259 were significantly higher than those at all other times except 13 hr, group sizes from 1300–1359 were significantly higher than those at 9–11, 14, 16, and 19 hr (Fisher's LSD).

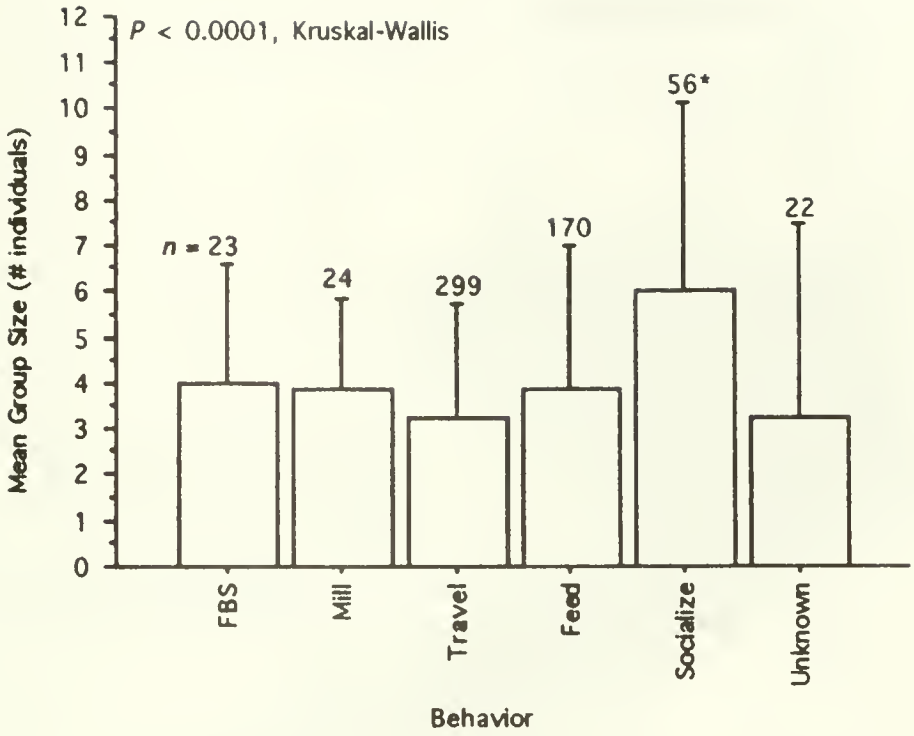


Figure 13. Mean group sizes by behavior, error bars indicate 1 SD. Socializing occurred in significantly larger groups than other behaviors ($P < 0.005$, Fisher's LSD).

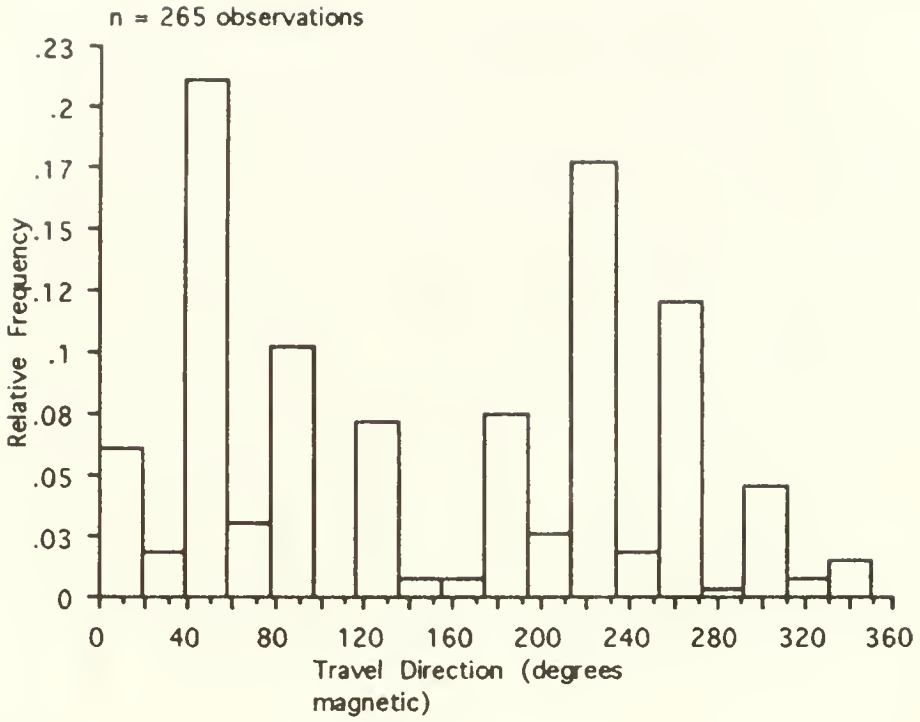


Figure 14. Histogram of observed travel directions.

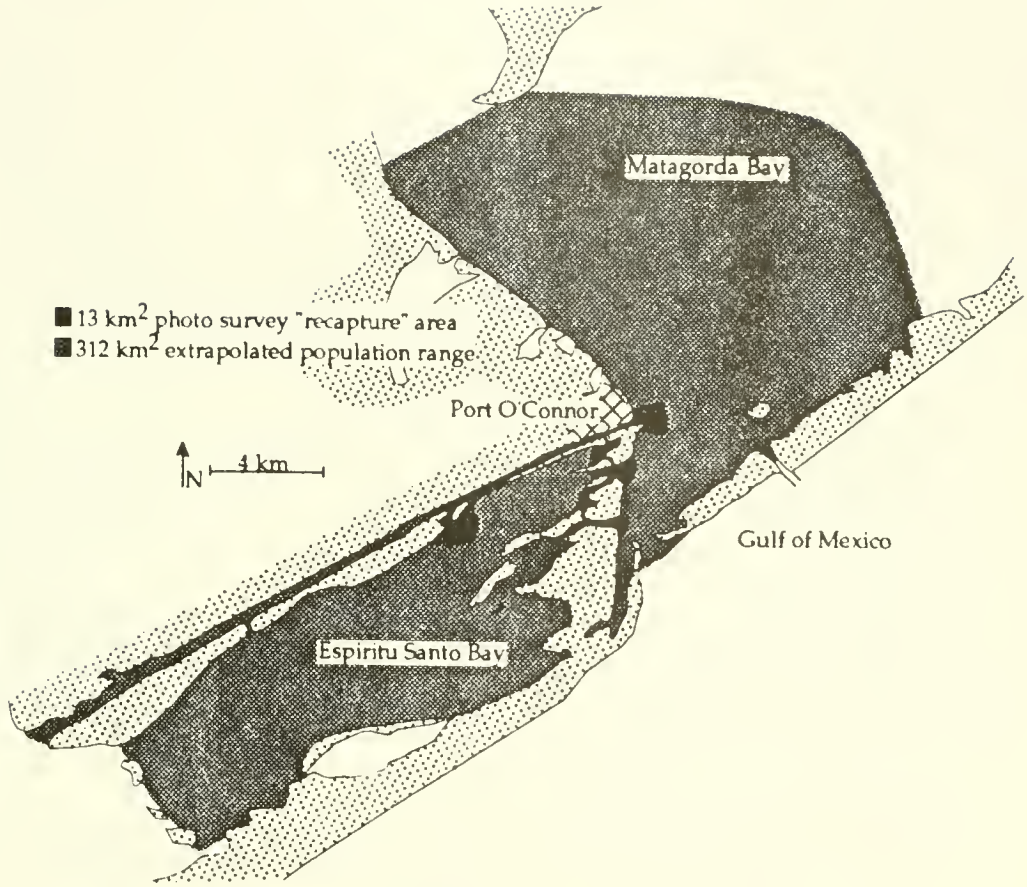


Figure 15. Assumed minimum area occupied by estimated dolphin population.

Table 1. Summary of radio tracking effort for dolphins in Matagorda, Texas, Bay 9 July–13 September 1992.

Radio	Freeze-brand	Date mounted	Date of last regular signal	Useful life span (days)	#Positions obtained	Area of range (km^2)
1	502	9 Jul 92	16 Aug 92	39	144	235
2	504	9 Jul 92	29 Jul 92	21	120	100
3	501	10 Jul 92	6 Sep 92	59	76	329
4	505	11 Jul 92	23 Jul 92	13	64	191
5	511	12 Jul 92	1 Aug 92	21	102	92
6	515	14 Jul 92	3 Aug 92	21	84	88
7	514	14 Jul 92	1 Aug 92	19	98	61
8	518	15 Jul 92	13 Sep 92	61	225	180
9	521	15 Jul 92	9 Aug 92	27	125	49
10	522	17 Jul 92	11 Aug 92	26	116	77
			Mean	30.7	115	140
			SD	16.85	45.5	90.7

Table 2. Summary of photographic survey effort for dolphins in Matagorda Bay, Texas, 14 May 1992–18 June 1993.

Survey	Dates	Total# photos	#Dolphins seen	#Freeze-brands seen	#Hours on water	#Hours with dolphins	Mean group size	SD	*n*	ER[a]
1	14 May 92–19 May 92	792	230	8	41.9	14.0	3.9	3.32	58	5.5
2[b]	6 Jul 92–30 Aug 92	2,196	1,180	106	800	60.7	3.3	2.71	368	
3[b]	4 Sep 92–6 Sep 92 11 Sep 92–12 Sep 92	180	67	2	30.3	4.5	2.6	2.37	26	
4	24 Oct 92–25 Oct 92	108	154	3	20.4	9.7	3.9	3.33	39	7.5
5	19 Dec 92–21 Dec 92	324	210	13	19.8	13.3	4.0	3.56	52	10.6
6	12 Jan 93–13 Jan 93	216	98	7	16.1	9.1	3.0	1.76	33	6.1
7	19 Mar 93–21 Mar 93	468	176	10	27.4	15.3	3.1	2.65	57	6.4
8[c]	24 May 93–25 May 93	36	10	1	1.5	.9	2	0.70	5	
9	15 Jun 93–18 Jun 93	252	111	8	25.7	8.9	4.4	3.79	25	4.3
Overall		4,572	2,236	158	983.1	136.4	3.5	2.86	648	6.5

[a] ER = encounter rate, #Dolphins seen/#Hours on water.
[b] Number of individuals photographed in corresponding elapsed time period. Some individuals contributed data to more than one stage.
[c] Ended early due to rain.

Table 3. Summary statistics for surfacing-interval data. Sample size (*n*) refers to the number of averaged 30-min samples used for individual dolphins, and sums to give the number of 30-min samples used for the Females, Males, and All rows.

	Dive Duration (sec)											
	Overall			Day			Night			Crepuscular		
Dolphin	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*
FB502	40.2	12.74	44	37.2	12.38	26	50.8	6.73	13	28.0	6.3	5
FB504	32.5	8.70	48	29.9	7.90	28	41.1	5.57	13	27.2	5.04	7
FB501	36.3	10.12	11	34.8	9.37	10	N/A	N/A	0	50.9	N/A	1
FB505	31.8	7.83	28	34.1	7.59	16	27.7	7.46	9	31.8	7.59	3
FB511	30.6	7.21	48	30.7	7.62	27	30.8	6.85	18	27.6	6.63	3
FB515	33.8	5.98	29	30.9	6.22	14	37.3	3.96	11	34.5	5.29	4
FB514	38.9	9.38	50	36.2	10.11	29	43.7	7.01	17	37.2	4.12	4
FB518	32.0	6.77	115	31.4	6.83	70	33.3	5.71	28	32.3	8.10	17
FB521	24.1	4.80	79	23.8	4.36	41	23.9	4..55	25	25.6	6.51	13
FB522	28.2	5.84	55	26.3	5.64	29	30.1	5.71	19	30.6	4.90	7
Females	31.3	4.58	5	30.1	4.36	5	23.9	5.67	4	34.1	10.03	5
Males	34.4	5.04	5	32.2	4.52	5	39.8	8.28	5	31.1	3.99	5
All radio tags	32.8	4.81	10	31.5	4.24	10	35.4	8.57	9	32.6	7.37	10

Table 3, continued.

	Surface Duration (sec)											
	Overall			Day			Night			Crepuscular		
Dolphin	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*
FB502	5.3	1.61	31	5.1	0.90	19	4.9	0.69	8	7.2	3.78	4
FB504	5.9	1.22	34	5.5	0.68	20	7.0	1.67	9	5.3	0.87	5
FB501	10.9	14.21	7	11.6	15.45	6	N/A	N/A	0	7.0	N/A	1
FB505	7.9	4.79	16	7.5	4.44	8	8.6	6.14	6	7.4	3.35	2
FB511	8.4	8.19	40	6.2	1.56	23	10.7	12.12	15	15.8	14.18	2
FB515	5.8	1.77	22	5.7	1.28	11	6.2	1.31	7	5.7	0.56	4
FB514	5.3	0.83	42	5.1	0.60	22	5.9	0.92	16	4.8	0.24	4
FB518	4.0	0.87	109	3.9	0.81	66	4.4	1.01	26	3.9	0.84	17
FB521	5.4	1.40	72	5.5	1.41	36	5.7	1.52	24	4.5	0.68	12
FB522	4.0	0.71	52	4.0	0.62	27	3.9	0.56	18	4.3	1.26	7
Females	7.7	2.22	5	7.3	2.53	5	7.8	2.31	4	8.1	4.46	5
Males	4.9	0.86	5	4.7	0.72	5	5.2	1.24	5	5.1	1.29	5
All radio tags	6.3	2.16	10	6.0	2.22	10	6.4	2.15	9	6.6	3.47	10

Table 3, continued.

	Dive Rate (dives/min)											
	Overall			Day			Night			Crepuscular		
Dolphin	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*
FB502	1.7	0.78	44	1.9	0.90	26	1.2	0.17	13	2.2	0.43	5
FB504	2.0	0.59	48	2.2	0.61	28	1.5	0.20	13	2.3	0.44	7
FB501	1.8	0.64	11	1.9	0.64	10	N/A	N/A	0	1.2	N/A	1
FB505	2.0	0.56	28	1.9	0.42	16	2.3	0.71	9	2.0	0.53	3
FB511	2.1	0.65	48	2.1	0.70	27	2.1	0.62	18	2.3	0.56	3
FB515	1.8	0.35	29	2.0	0.39	14	1.6	0.18	11	1.8	0.28	4
FB514	1.7	0.49	50	1.8	0.57	29	1.4	0.25	17	1.6	0.18	4
FB518	2.0	0.44	115	2.0	0.44	70	1.9	0.32	28	2.0	0.58	17
FB521	2.6	0.59	79	2.6	0.55	41	2.6	0.68	25	2.5	0.57	13
FB522	2.2	0.49	55	2.4	0.54	29	2.1	0.39	19	2.0	0.29	7
Females	2.1	0.33	5	2.1	0.29	5	2.2	0.42	5	2.0	0.50	5
Males	1.9	0.22	5	2.1	0.24	5	1.6	0.37	5	2.0	0.27	5
All radio tags	2.0	0.27	10	2.1	0.25	10	1.9	0.46	10	2.0	0.38	10

Table 4. Mean half-weight index of association values for non-calf freeze-branded dolphins seen at least five times.

Dolphin	In assoc. with	Mean	SD	*n*	Min.	Max.	Median
FB502	Males	0.141	0.070	2	0.091	0.190	0.141
FB503	Males	0.131	0.045	3	0.100	0.182	0.111
FB504	Males	0.102	0.048	6	0.059	0.190	0.091
FB505	Males	N/A	N/A	0	N/A	N/A	N/A
FB507	Males	0.153	0.082	2	0.095	0.211	0.153
FB511	Males	0.107	0.036	4	0.069	0.143	0.108
FB512	Males	0.144	0.054	2	0.105	0.182	0.144
FB514	Males	0.077	N/A	1	0.077	0.077	0.077
FB515	Males	0.084	0.033	3	0.057	0.121	0.074
FB516	Males	0.080	N/A	1	0.080	0.080	0.080
FB518	Males	0.083	0.020	5	0.059	0.114	0.080
FB521	Males	0.104	0.030	5	0.074	0.146	0.111
FB522	Males	0.106	0.022	7	0.069	0.125	0.114
FB538	Males	0.161	0.073	5	0.077	0.250	0.182
FB502	Females	N/A	N/A	0	N/A	N/A	N/A
FB503	Females	0.111	0.052	2	0.074	0.148	0.111
FB504	Females	0.092	0.024	4	0.057	0.114	0.098
FB505	Females	0.087	0.034	2	0.063	0.111	0.087
FB507	Females	0.127	0.023	2	0.111	0.143	0.127
FB511	Females	0.067	N/A	1	0.067	0.067	0.067
FB512	Females	0.134	0.053	3	0.077	0.182	0.143
FB514	Females	0.148	0.055	3	0.111	0.211	0.121
FB515	Females	0.118	0.048	3	0.063	0.148	0.143
FB516	Females	0.286	N/A	1	0.286	0.286	0.286
FB518	Females	0.108	0.054	2	0.069	0.146	0.108
FB521	Females	0.071	0.005	2	0.067	0.074	0.071
FB522	Females	0.125	0.059	2	0.083	0.167	0.125
FB538	Females	0.094	0.034	3	0.074	0.133	0.074

Table 4, continued.

Dolphin	In assoc. with	Mean	SD	*n*	Min.	Max.	Median
FB502	All	0.141	0.070	2	0.091	0.190	0.141
FB503	All	0.123	0.042	5	0.074	0.182	0.111
FB504	All	0.098	0.044	8	0.057	0.190	0.091
FB505	All	0.087	0.034	2	0.063	0.111	0.087
FB507	All	0.140	0.051	4	0.095	0.211	0.127
FB511	All	0.099	0.036	5	0.067	0.143	0.083
FB512	All	0.138	0.047	5	0.077	0.182	0.143
FB514	All	0.130	0.057	4	0.077	0.211	0.116
FB515	All	0.101	0.041	6	0.057	0.148	0.098
FB516	All	0.183	0.146	2	0.080	0.286	0.183
FB518	All	0.090	0.030	7	0.059	0.146	0.080
FB521	All	0.095	0.029	7	0.067	0.146	0.077
FB522	All	0.103	0.022	8	0.069	0.125	0.105
FB538	All	0.136	0.068	8	0.074	0.250	0.114

Table 5. Mean half-weight index of association values for same-sex and opposite-sex associations among freeze-branded dolphins. Values are derived from means of individuals shown in Table 4.

Pair	Mean	SD	Min.	Max.	*n*
Male-Male	0.110	0.032	0.080	0.160	8
Female-Female	0.098	0.026	0.070	0.130	6
Opposite-sex	0.129	0.056	0.080	0.290	12
Overall	0.119	0.027	0.090	0.180	14

Table 6. Primary and secondary affiliates of the six female and eight male freeze-branded dolphins most frequently sighted.

Sex	Pregnant (P) or with calf (C)	Age	Dolphin	1° & 2° affiliate	H-W index	Age	Sex	Pregnant (P) or with calf (C)
M		16	FB502	FB504	0.190	18	M	
				FB522	0.091	8	M	
F	P, C	21	FB503	FB512	0.182	7	M	
				FB515	0.148	12	F	C
M		18	FB504	FB502	0.190	16	M	
				FB521	0.114	31	F	P, C
F	P	8	FB505	FB507	0.111	16	F	P, C
				FB515	0.063	12	F	C
F	P, C	16	FB507	FB514	0.211	19	M	
				FB515	0.143	12	F	C
F	P, C	19	FB511	FB512	0.143	7	M	
				FB538	0.133	11	M	
M		7	FB512	FB503	0.182	21	F	P, C
				FB538	0.182	11	M	
				FB511	0.143	19	F	P, C

Table 6, continued.

Sex	Pregnant (P) or with calf (C)	Age	Dolphin	1° & 2° affiliate	H-W index	Age	Sex	Pregnant (P) or with calf (C)
M		19	FB514	FB507	0.211	16	F	P, C
				FB515	0.121	12	F	C
F	C	12	FB515	FB503	0.148	12	F	P, C
				FB507	0.143	21	F	P, C
M		10	FB516	FB519	0.286	31	F	P?
				FB518	0.080	11	M	
M		11	FB518	FB521	0.146	31	F	P, C
				FB522	0.114	8	M	
F	P, C	31	FB521	FB518	0.146	11	M	
				FB504	0.114	18	M	
M		8	FB522	FB521	0.167	31	F	P, C
				FB518	0.114	11	M	
M		11	FB538	FB534	0.250	9	M	
				FB536	0.200	10	M	

Table 7. Observed frequencies of behaviors in each habitat type.

Behavior	Channel	Bay	Jetty	Offshore	Total	
FBS	1	22	0	1	24	3.9%
Feed	104	50	19	0	173	28.4%
Socialize	20	32	3	2	57	9.4%
Travel	172	119	18	0	309	50.7%
Mill	6	15	3	0	24	3.9%
Unknown	10	10	2	0	22	3.6%
Total	313	248	45	3	609	100%

Table 8. Mean direction of travel for eight surveys.

Survey	Mean direction (degrees magnetic)	95%CI	*n*
May 1992	45	>90	14
July–August 1992	1	25	151
September 1992	342	>90	10
October 1992	8	50	12
December 1992	310	42	23
January 1993	10	45	24
March 1993	8	53	21
June 1993	283	62	10

Table 9. Bailey-modified Petersen estimates of population size.

Survey	#Dolphins seen, n	#Freeze-brands seen, m	#Marked, M	Estimate, $\hat{N}$	±95% CI	Density ($\hat{N}$/312 km^2)
May-92	65	5	17	187	132.1	0.60
Oct-92	50	1	17	434	480.8	1.39
Dec-92	92	6	17	226	150.5	0.72
Jan-93	51	7	17	111	66.4	0.36
Mar-93	124	8	17	236	141.0	0.76
Jun-93	27	4	18	101	73.1	0.32
All 6	409	31	17	218	71.4	0.70

Table 10. Stages of wedge-biopsy healing.

Stage	Days post biopsy	n[a]	Observations
0	0	2	Oval, deeply pink to red wound, several mm deep. No other discoloration. Size ~ 30 mm long x 20 mm high.
1	8–18	4	Oval wound, pinkish to white coloration. Darker spot at center (4–5 mm diameter). Skin at edge of wound may be darker than surrounding normal skin (2.7–3.3 mm band). Wound may be surrounded by lighter gray halo fading into normal skin.
2	15–26	3	Pinkness absent. Oval shaped white wound may have darker spot in center (3.6 mm diameter). Lighter gray halo may surround wound in 3.9 mm band.
3	40–42	2	White spot. No other discoloration. No apparent indentation.
4	≥ 61–476	18	Normal or nearly normal pigmentation. Wound may be indented a few mm. Appearance varies from indistinguishable to slightly lighter or darker than surrounding normal skin.

[a] Number of individuals photographed in corresponding elapsed time period. Some individuals contributed data to more than one stage.

APPENDIX 1

SUMMARY INFORMATION FOR ALL DOLPHINS CAPTURED
(portions after Sweeney 1992)

Name	Sex	Age[a] (yr)	Comments
FB501 (RT3)	F	17	Tagged 10 July 1992. Initially identified in May 1992 survey.
FB502 (RT1)	M	16	Tagged 9 July 1992. Initially identified in May 1992 survey.
FB503	F	21	Tagged 10 July 1992. Pregnant (1st trimester), lactating. Mother of FB508.
FB504 (RT2)	M	18	Tagged 9 July 1992. Initially identified in May 1992 survey.
FB505 (RT4)	F	8	Tagged 11 July 1992. Pregnant (1st trimester).
FB506	M	11	Tagged 9 July 1992.
FB507	F	16	Tagged 11 July 1992. Mother of FB509. Pregnant (1st trimester). Initially identified in May 1992 survey.
FB508	M	2	Tagged 10 July 1992. Calf of FB503. FB looks like "500".

[a] From inspection of dental growth layer groups unless otherwise noted. Age data provided by NMFS. Matagorda Bay dolphins may be smaller than other Gulf coast dolphins. Based on length, age of these dolphins was underestimated. There was a discrepancy of 4.5 ± 7.40 (SD) years (younger) between length based estimates and the more accurate GLG estimates.

Appendix 1, continued.

Name	Sex	Age (yrs)	Comments
FB509	F	3	Tagged 11 July 1992. Calf of FB507. Initially identified in May 1992 survey.
FB510	M	2[b]	Tagged 11 July 1992.
FB511 (RT5)	F	19	Tagged 12 July 1992. Mother of FB513. Pregnant (1st trimester), lactating.
FB512	M	7	Tagged 11 July 1992.
FB513	F	1[b]	Tagged 12 July 1992. Calf of FB511
FB514 (RT7)	M	19	Tagged 14 July 1992.
FB515 (RT6)	F	12	Tagged 14 July 1992. Mother of FB517. Lactating.
FB516	M	10	Tagged 14 July 1992.
FB517	F	2[b]	Tagged 14 July 1992. Calf of FB515. "51" of left side of fin unreadable. Dead: TMMSN ID# PO249. Collected 13 September 1992. Last seen 6 Sepember 1992. Died of intestinal infarction (necrosis due to twisted intestine) unrelated to capture.
FB518 (RT8)	M	11	Tagged 15 July 1992.

[b] No tooth collected. Age estimate based on length, from Sweeney (1992).

Appendix 1, continued.

Name	Sex	Age (yrs)	Comments
FB519	F	31	Tagged 14 July 1992. Possibly pregnant (early).
FB520	M	2[b]	Tagged 15 July 1992. Calf of FB521.
FB521 (RT9)	F	31	Tagged 15 July 1992. Weak cross bar on "2", left side of fin. Mother of FB 520. Pregnant (1st trimester), lactating.
FB522 (RT10)	M	8	Tagged 15 July 1992. Initially identified in May, 1992 survey.
FB523	F	34	Tagged 17 July 1992.
FB524	M	11	Tagged 17 July 1992.
FB525	F	3–4[b]	Tagged 17 July 1992.
FB526	M	10	Tagged 17 July 1992. Middle bar of "6" poor on left side fin.
FB527	F	22	Tagged 17 July 1992. Pregnant (1st trimester), lactating.
FB528	M	3–5[b]	Tagged 17 July 1992.
FB529	F	6	Tagged 18 July 1992.
FB530	M	22	Tagged 18 July 1992.
FB531	F	3–4[b]	Tagged 18 July 1992.

Appendix 1, continued.

Name	Sex	Age (yrs)	Comments
FB532	M	21	Tagged 18 July 1992.
FB534	M	9	Tagged 19 July 1992.
FB536	M	10	Tagged 19 July 1992. Brand looks like "535"
FB538	M	11	Tagged 19 July 1992. Initially identified in May, 1992 survey.
Rototag 412	M	2[b]	Tagged 10 July 1992. Not freeze-branded.

APPENDIX 2

SUMMARY OF CAPTURE INFORMATION

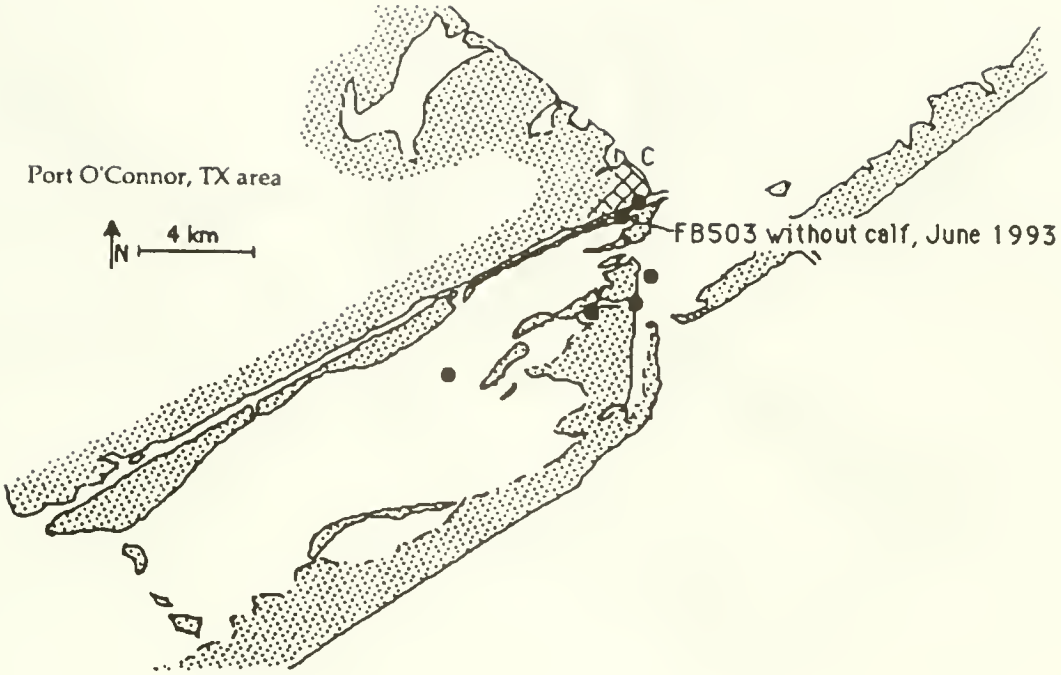
Date	Set	Time	Dolphins	Location
9 July 1992	Set 1	1010	FB502	28° 25.26'N, 96° 27.14'W, 500 m NW of Mitchell's Cut.
9 July 1992	Set 2	1250	FB504	28° 24.68'N, 96° 26.36'W. A few 100m NW of Mitchell's Cut.
9 July 1992	Set 3	1440	FB506	Unknown, probably near Teller Pt.
10 July 1992	Set 1	0758	FB501	28° 24.04'N, 96° 22.82'W. Matagorda Bay, along shore, half way between Decros Pt. and base of Big Jetties.
10 July 1992	Set 2	1249	FB503, FB508, Rototag 412	Matagorda Bay, near Port O'Connor, along shore somewhere between POC jetties and Broad Bayou.
11 July 1992	Set 1	0925	FB505	28° 19.78'N, 95° 29.87'W, 1 mi W of Army Hole.

Appendix 2, continued.

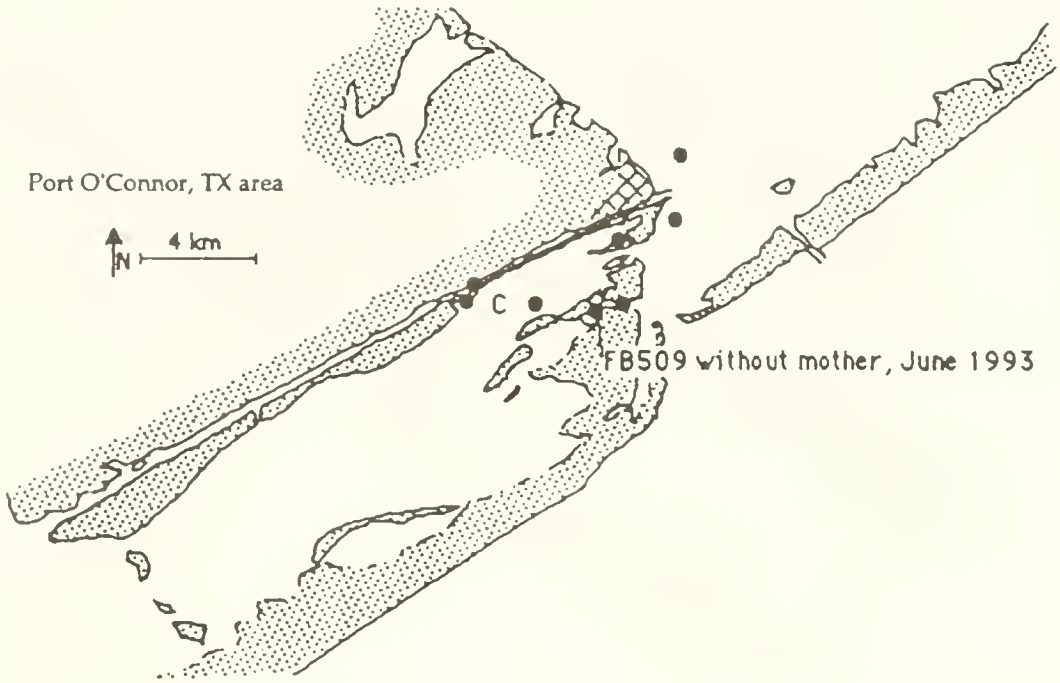
Date	Set	Time	Dolphins	Location
11 July 1992	Set 2	1127	FB510	28° 25.22'N, 96° 27.66'W. Esp. Bay, a few 100m NW of Bill Day's Reef.
11 July 1992	Set 3	1330	FB512	28° 24.60'N, 96° 28.34'W. Esp. Bay, a few 100m NE of Ferry Channel Cut.
11 July 1992	Set 4	1500	FB507, FB509	28° 24.29'N, 96° 28.03'W. Esp. Bay, a few 100m NE of Ferry Channel Cut.
12 July 1992	Set 1	1035	FB513, FB511	500 m N of POC jetties.
14 July 1992	Set 1	0745	FB515, FB517, FB514, FB507, FB509	1 km N of POC jetties. 28° 28.07'N, 96° 24.90'W.
14 July 1992	Set 2	1311	FB516, FB519	28° 29.72'N, 96° 27.02'W. About 100m NW of La Salle Bayou, Matagorda Bay.
15 July 1992	Set 1	0800	FB518, FB520, FB521	28° 29.05'N, 96° 26.05'W. Matagorda Bay, 1.5 mi N of POC Jetties, 400m from shore and inlet.

Appendix 2, continued.

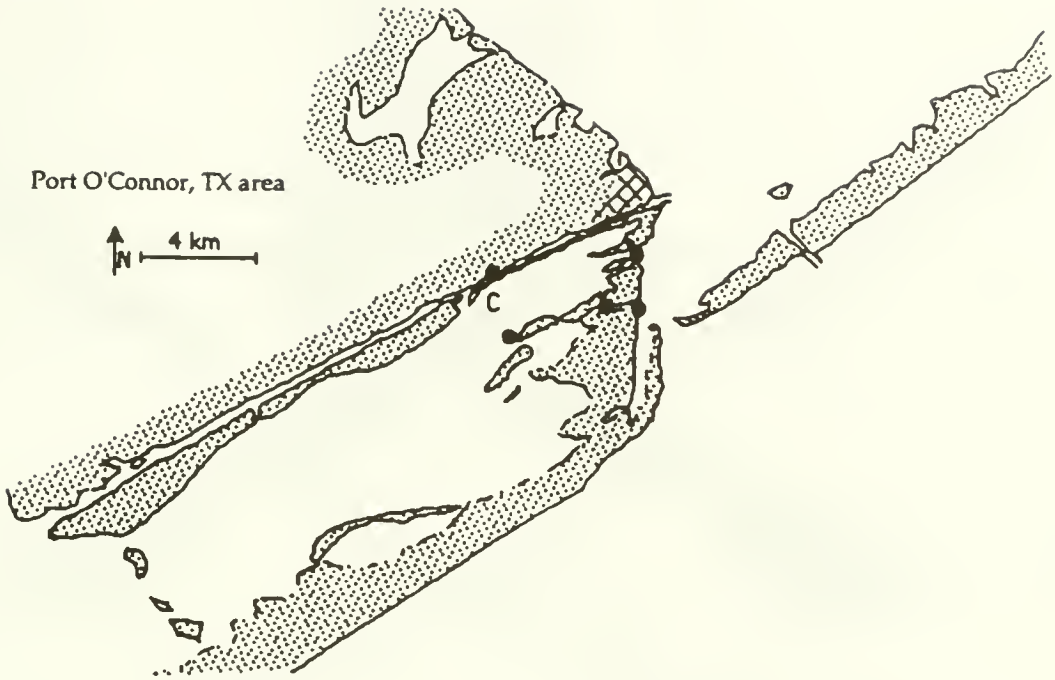
Date	Set	Time	Dolphins	Location
17 July 1992	Set 1	0920	FB522, FB524, FB526, FB528	28° 29.58'N, 96° 18.60'W. Matagorda Bay, NW of Club Airfield along Matagorda Peninsula, near pier/jetty.
17 July 1992	Set 2	1440	FB523, FB525, FB527	28° 34.18'N, 96° 10.45'W. Matagorda Bay, off Matagorda Peninsula about 9 mi NE of Big Jetties.
18 July 1992	Set 1	0830	FB531, FB529	28° 32.70'N, 96° 13.06'W. Matagorda Bay, off Matagorda Peninsula about 8 mi NE of Big Jetties.
18 July 1992	Set 2	1228	FB530, FB532	28° 34.33'N, 96° 09.75'W. Matagorda Bay, off Matagorda Peninsula about 14 mi NE of Big Jetties.
19 July 1992	Set 1	0735	FB534, FB536, FB538	Boggy Bayou 4 km N of POC Pier.



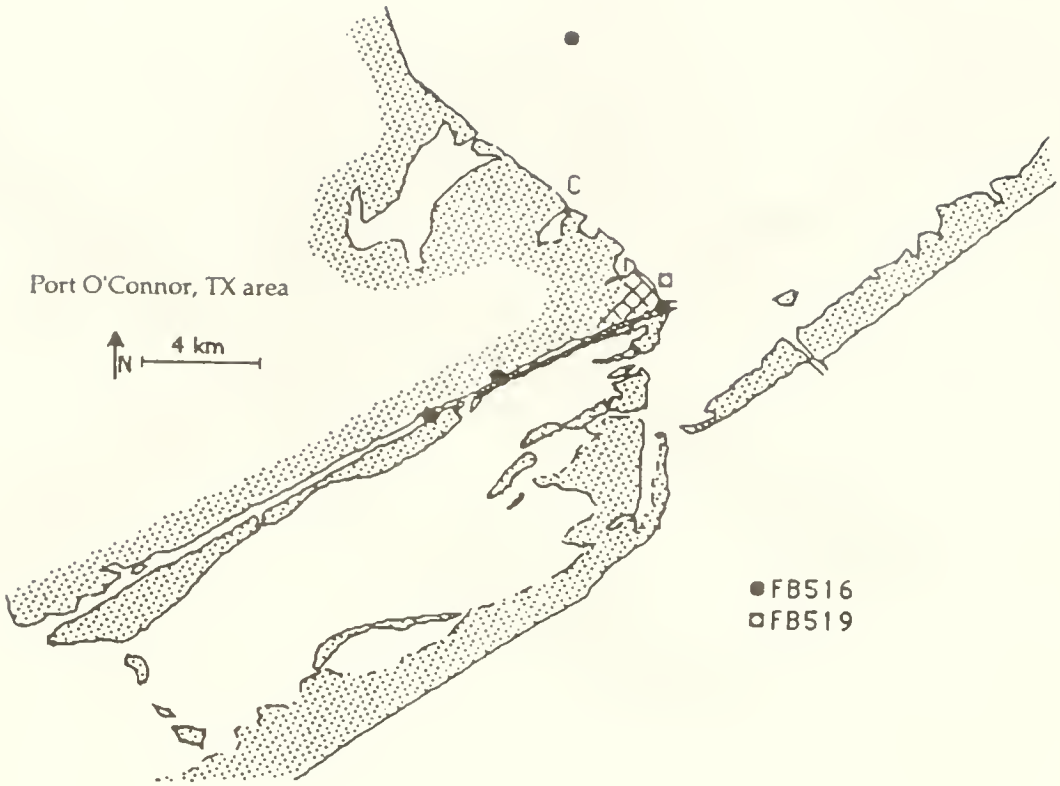
Appendix 3a. Sightings of FB503 and calf, FB508, during the nine photo-identification surveys. "C" denotes the capture location.



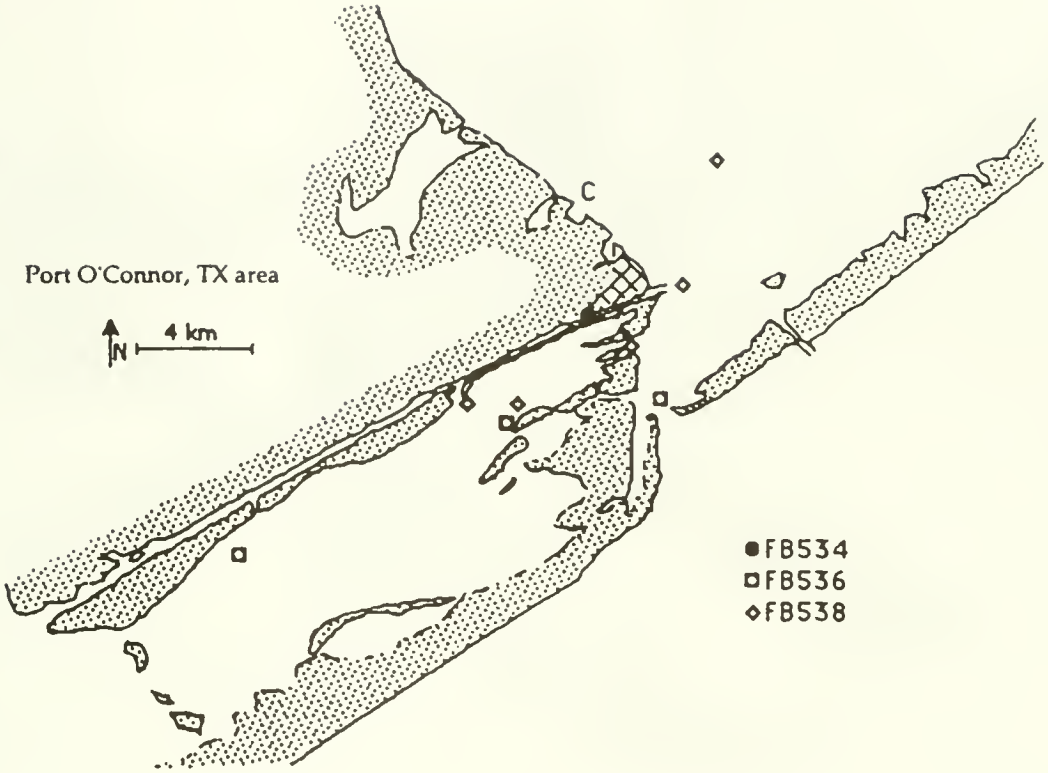
Appendix 3b. Sightings of FB507 and calf, FB509, during the nine photo-identification surveys. "C" denotes the capture location.



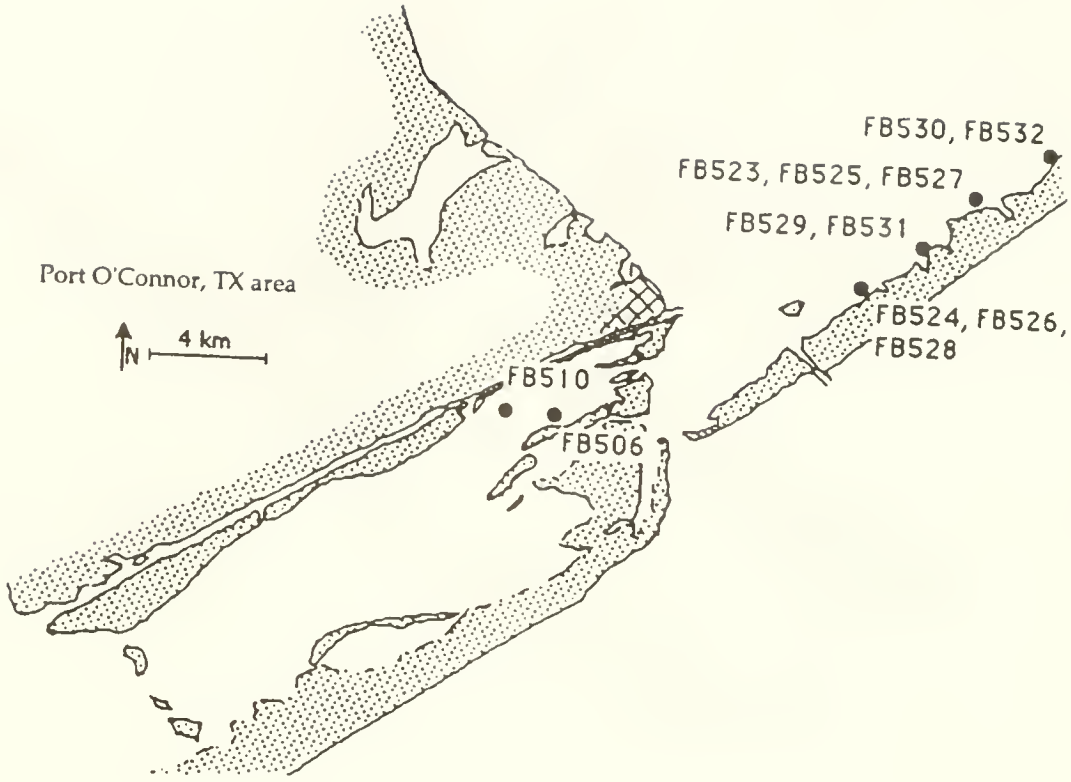
Appendix 3c. Sightings of FB512 during the nine photo-identification surveys. "C" denotes the capture location.



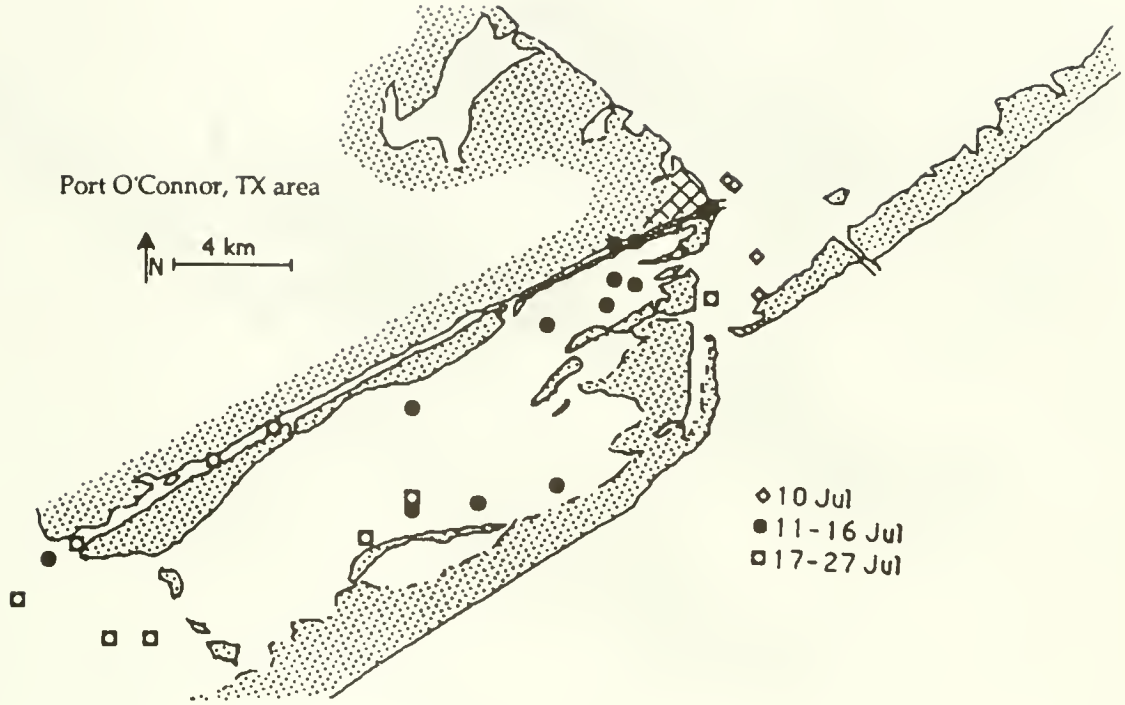
Appendix 3d. Sightings of FB516 and FB519 (captured together), during the nine photo-identification surveys. "C" denotes the capture location.



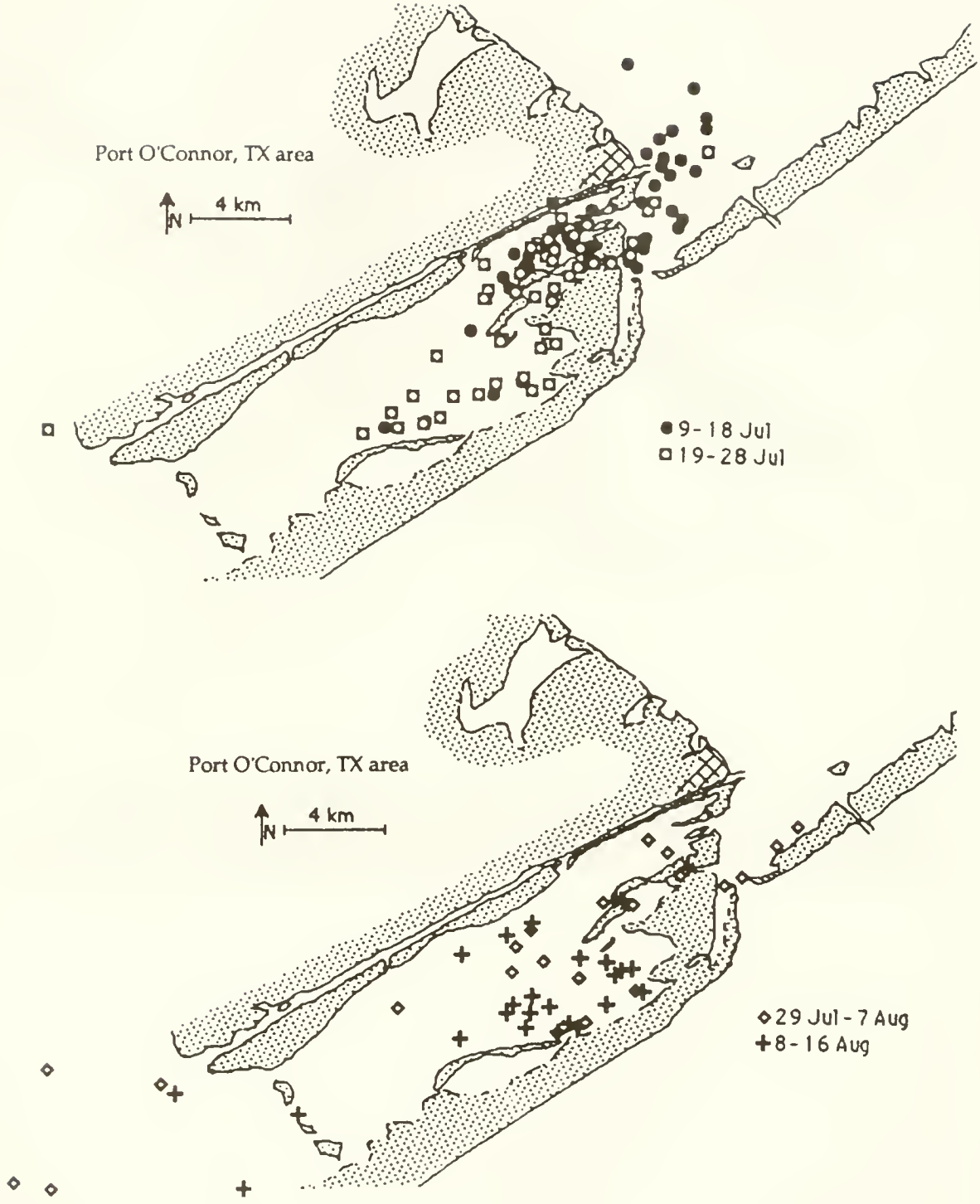
Appendix 3e. Sightings of FB534, FB536, and FB538 (captured together), during the nine photo-identification surveys. "C" denotes the capture location.



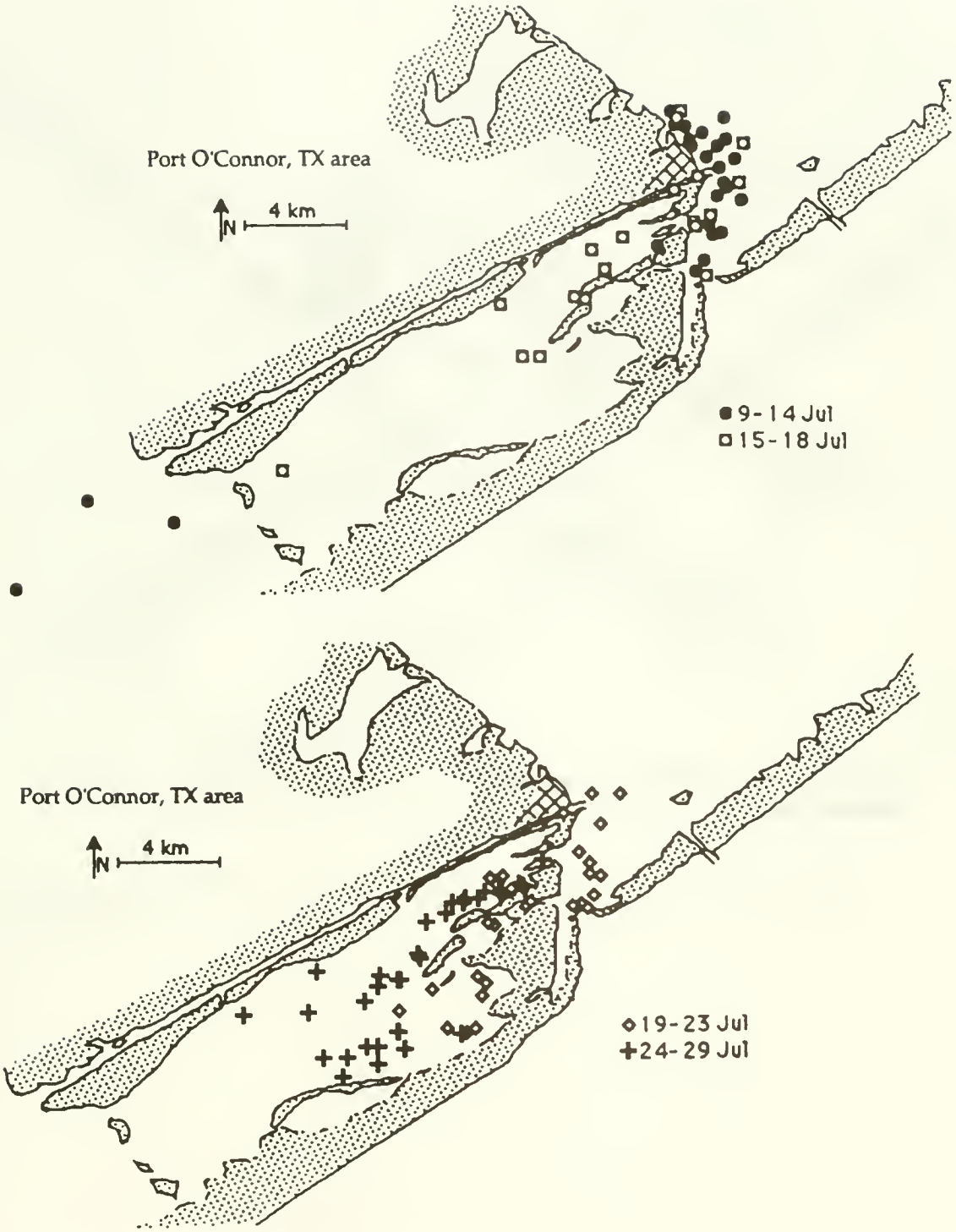
Appendix 3f. Capture locations of freeze-branded dolphins not seen during the nine photo-identification surveys.



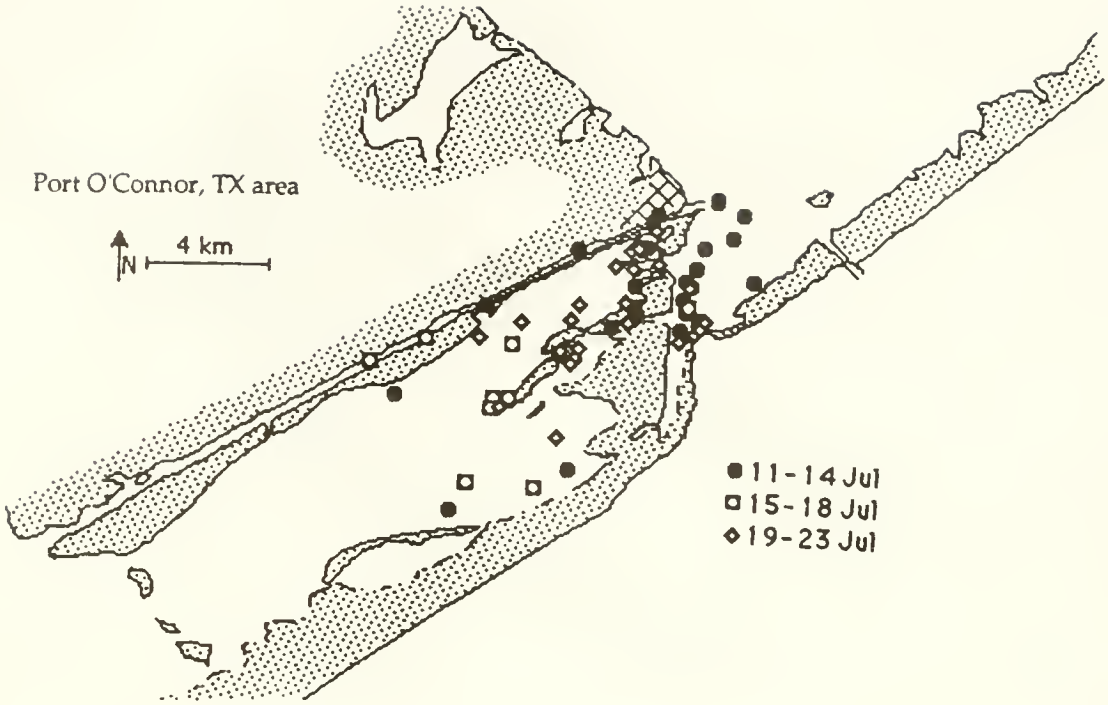
Appendix 4a. FB501 radio-telemetered and sighted positions during tracking period. From 27 July–6 September FB501 was out of range (presumably in San Antonio Bay, positions not shown).



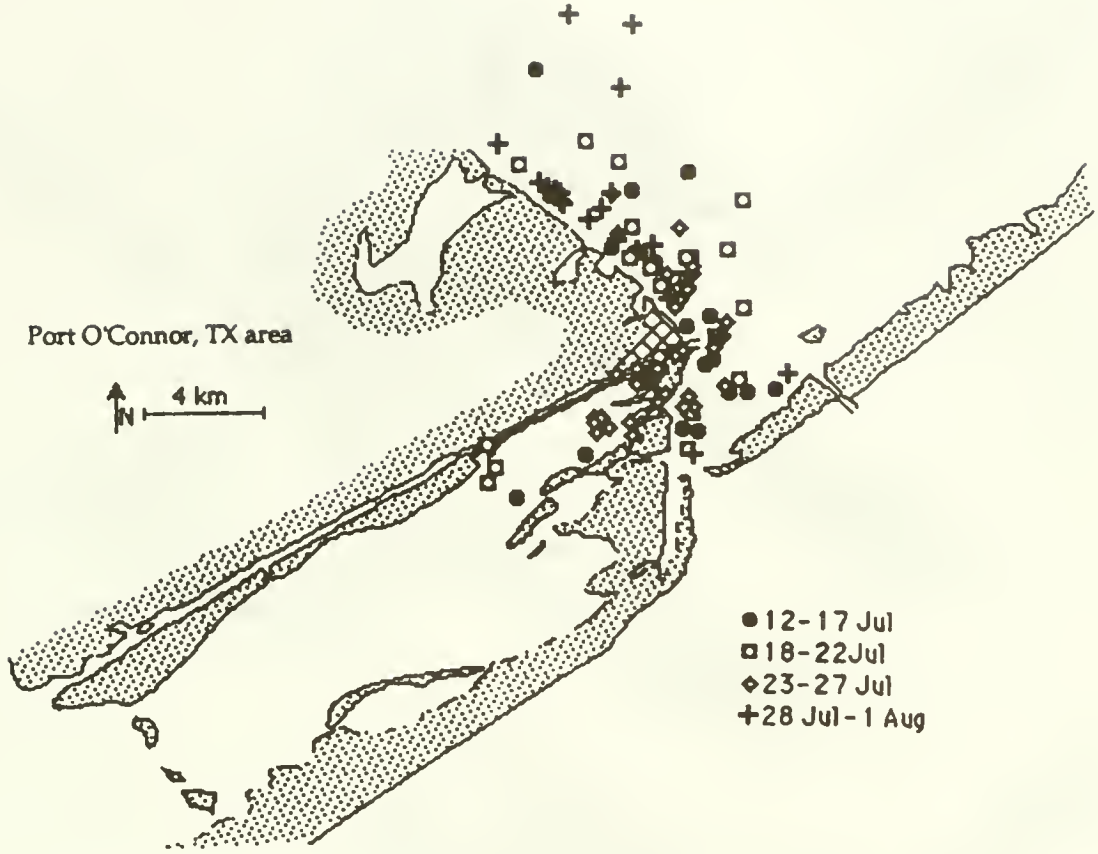
Appendix 4b. FB502 radio-telemetered and sighted positions during tracking period.



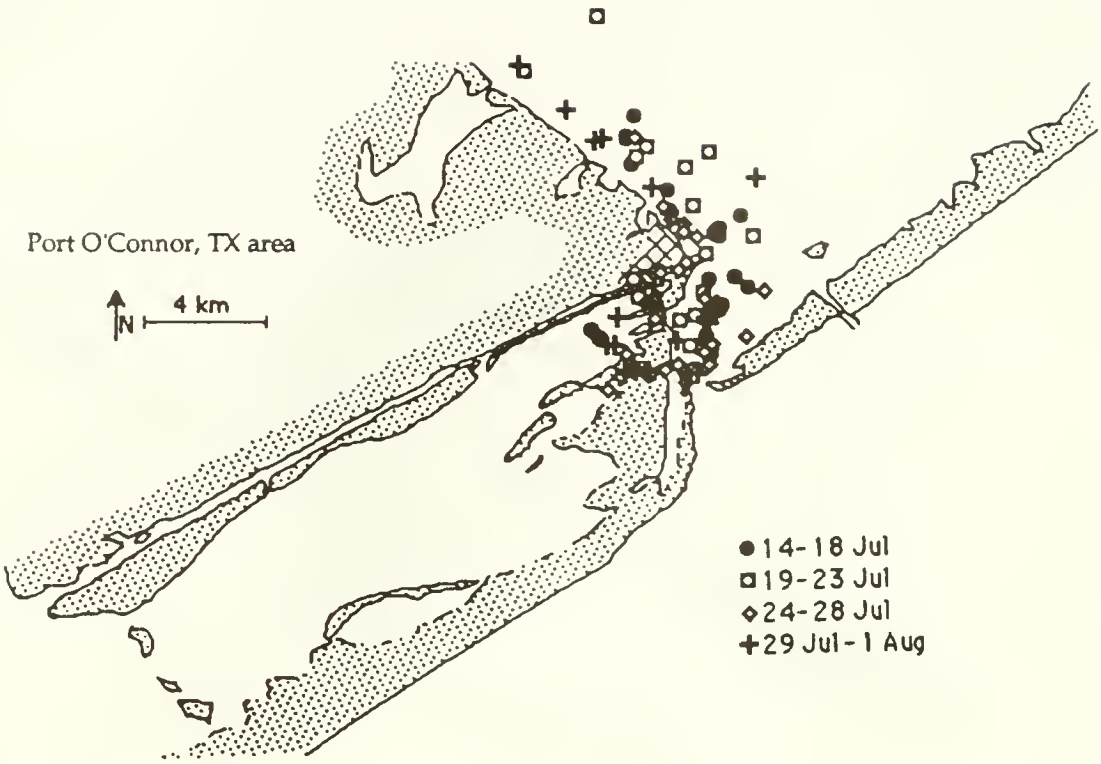
Appendix 4c. FB504 radio-telemetered and sighted positions during tracking period.



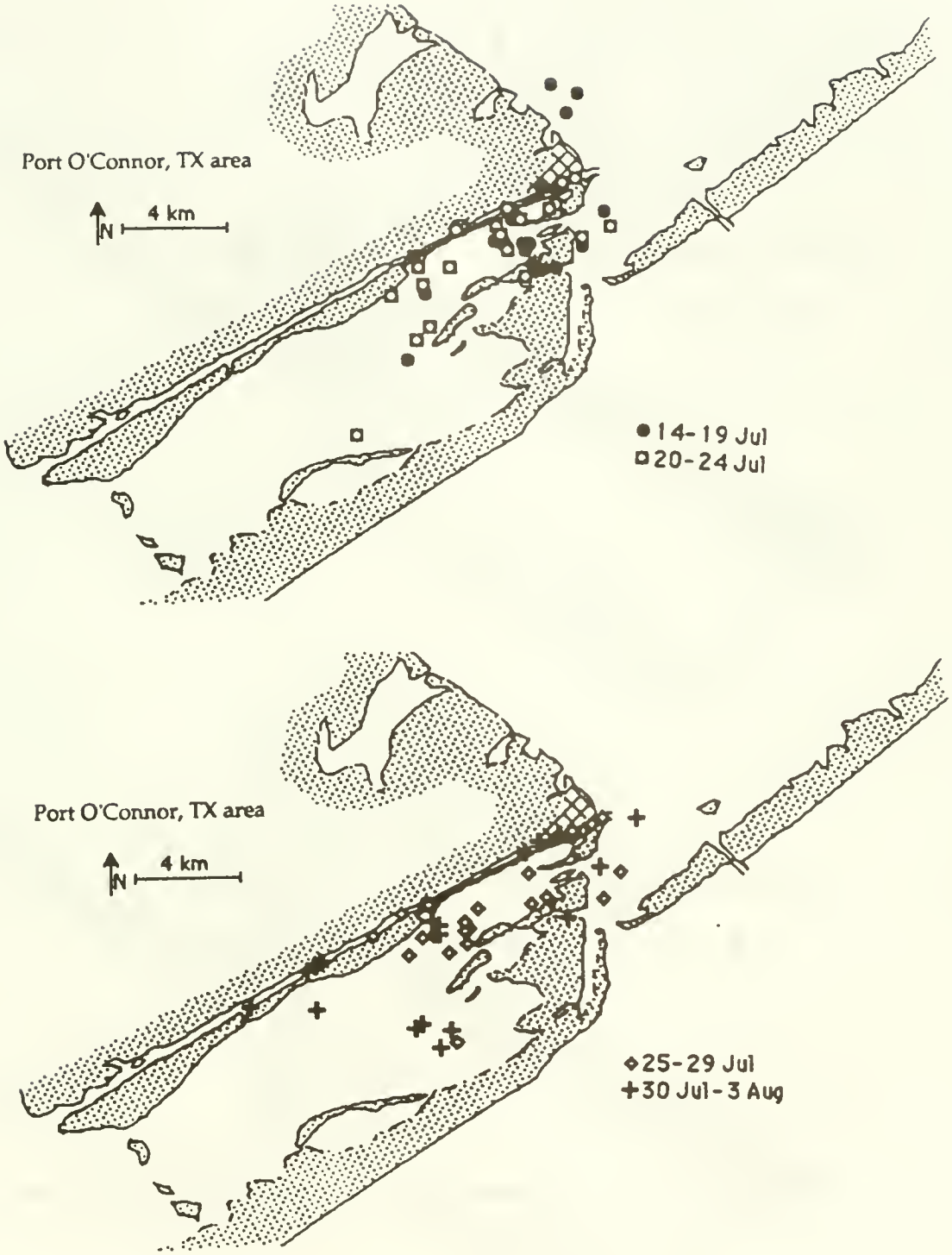
Appendix 4d. FB505 radio-telemetered and sighted positions during tracking period.



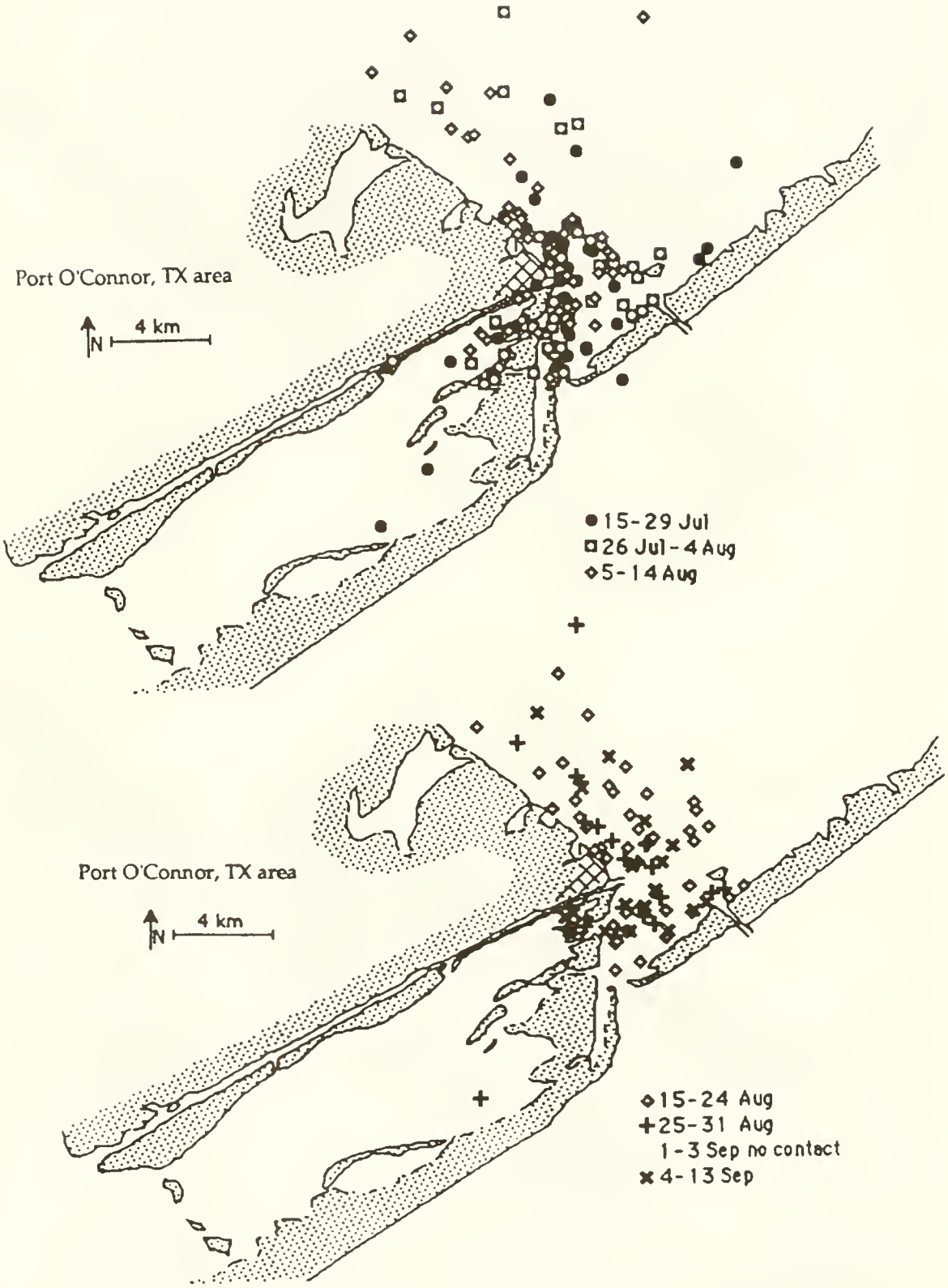
Appendix 4e. FB511 radio-telemetered and sighted positions during tracking period.



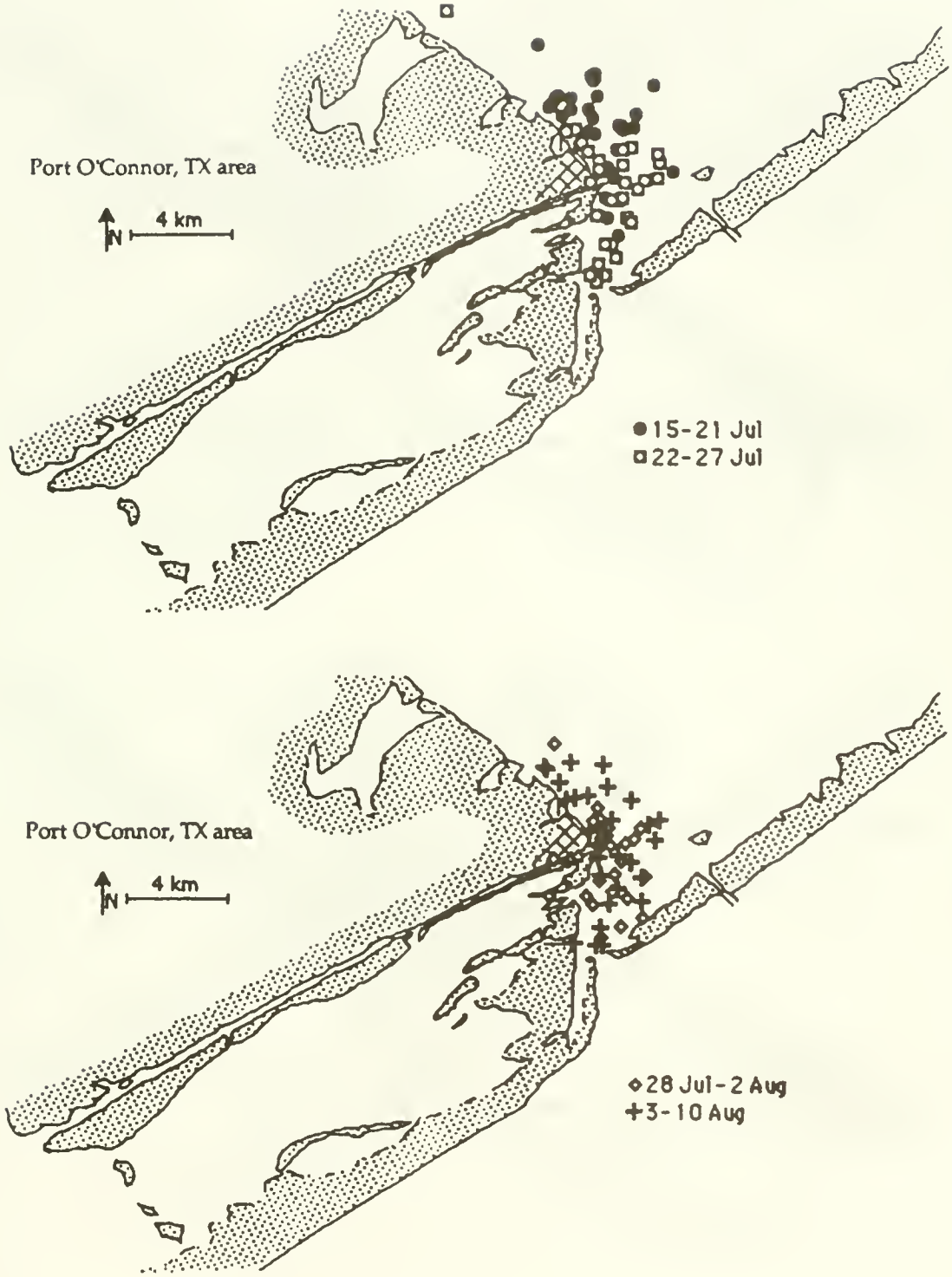
Appendix 4f. FB514 radio-telemetered and sighted positions during tracking period.



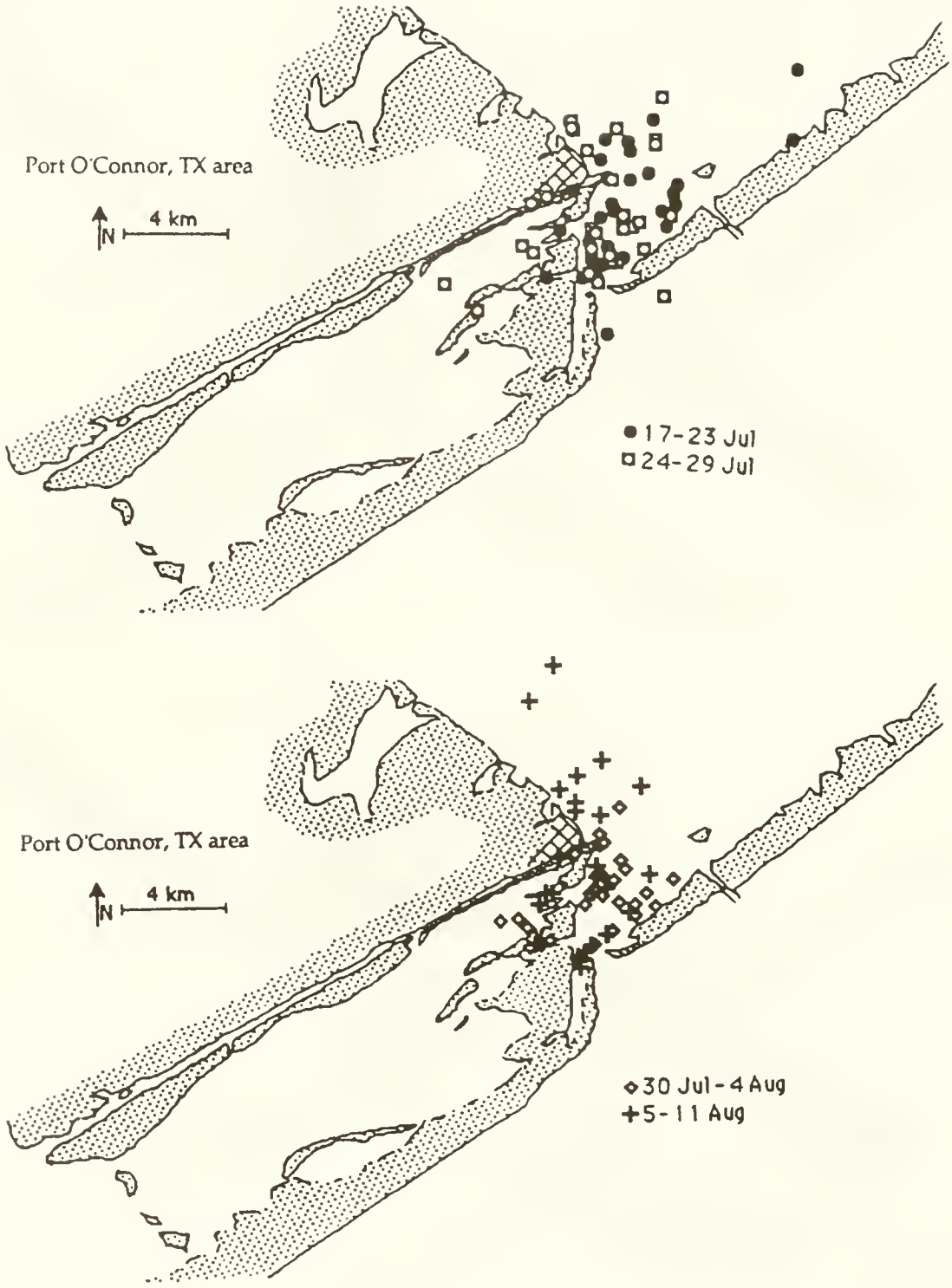
Appendix 4g. FB515 radio-telemetered and sighted positions during tracking period.



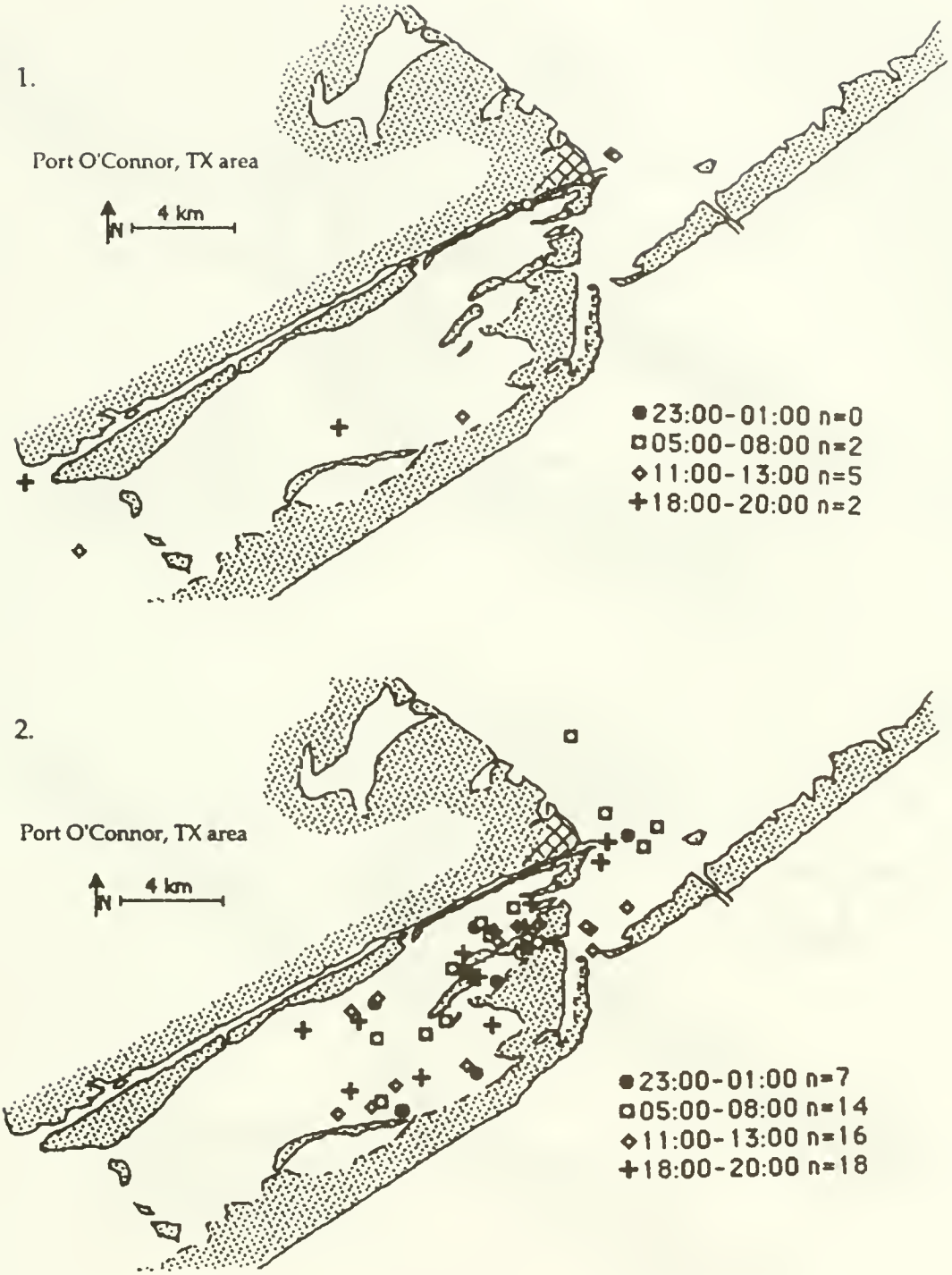
Appendix 4h. FB518 radio-telemetered and sighted positions during tracking period.



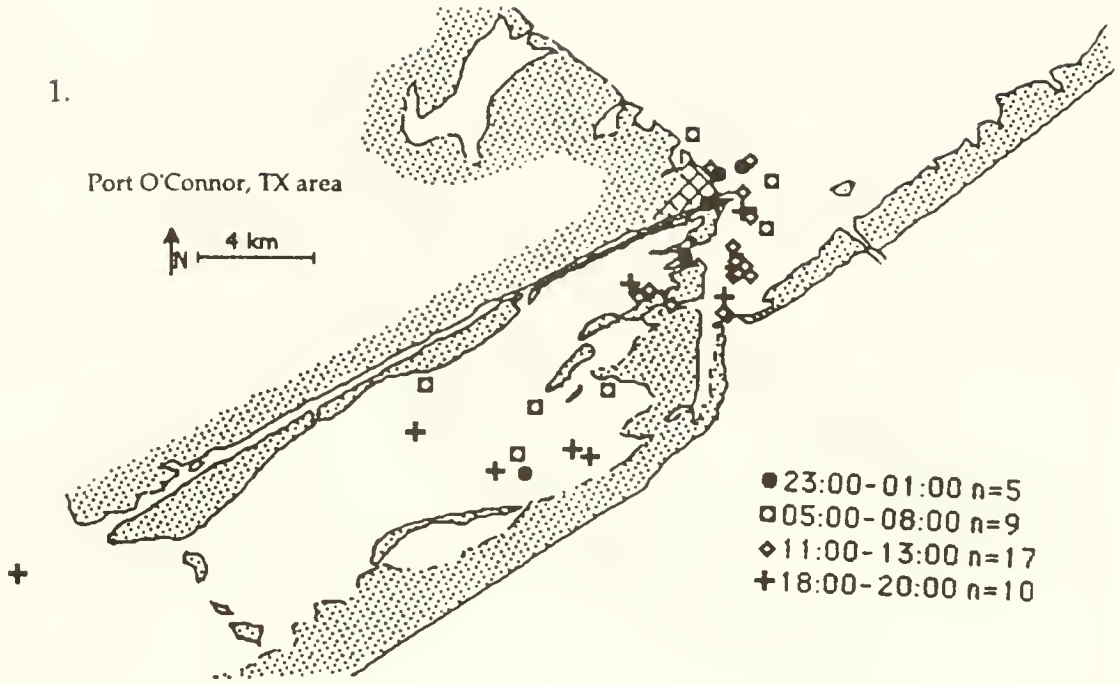
Appendix 4i. FB521 radio-telemetered and sighted positions during tracking period.

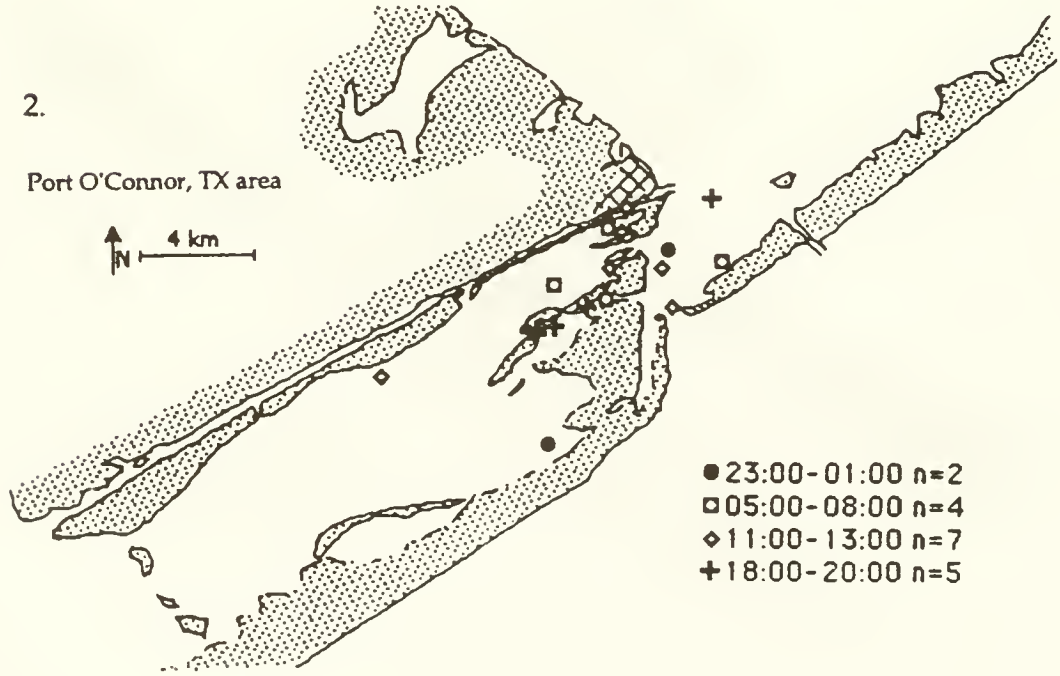


Appendix 4j. FB522 radio-telemetered and sighted positions during tracking period.

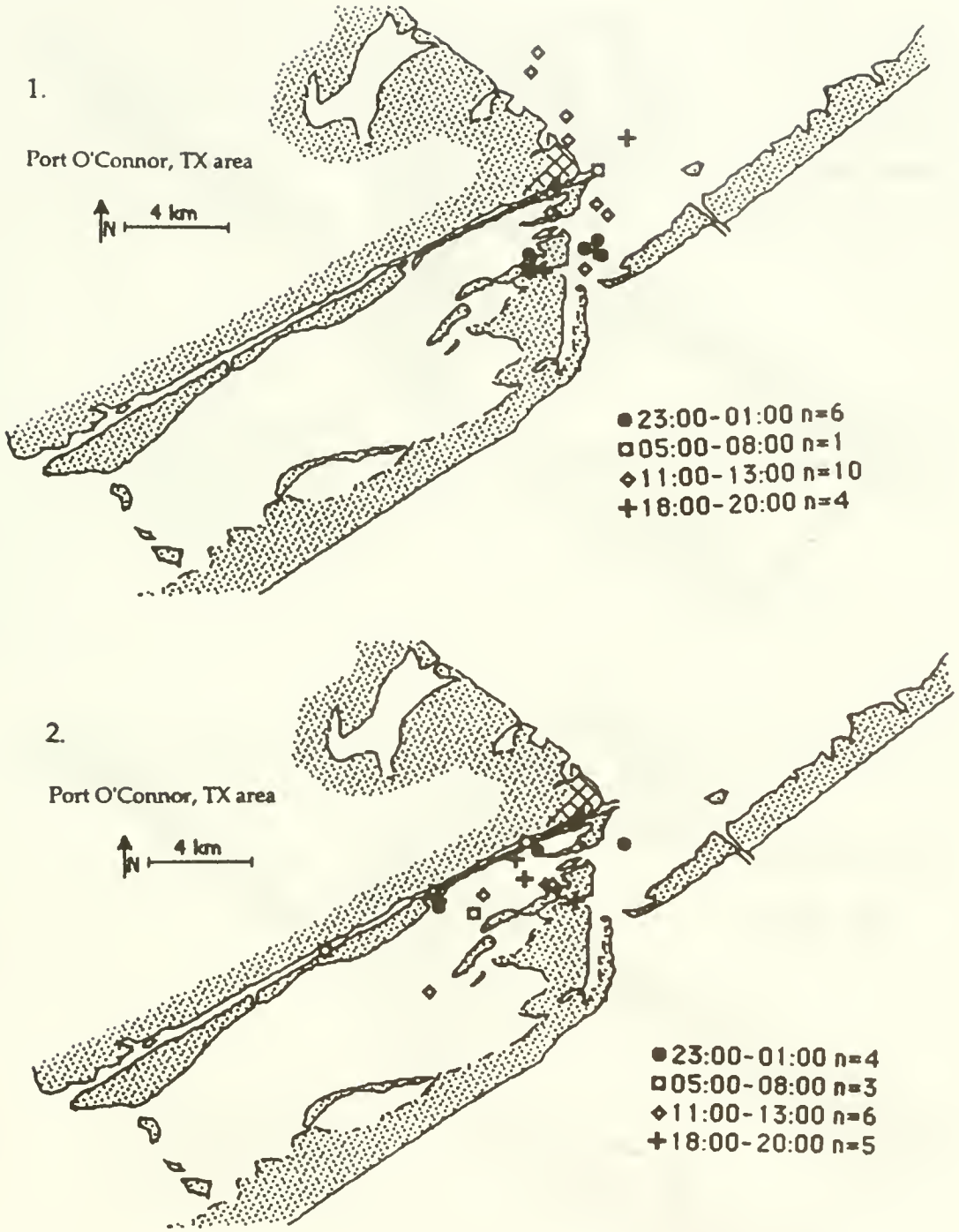


Appendix 5a. Positions of FB501 (1) and FB502 (2) by time of day over the radio-tracking period, from radio-telemetry and sightings.

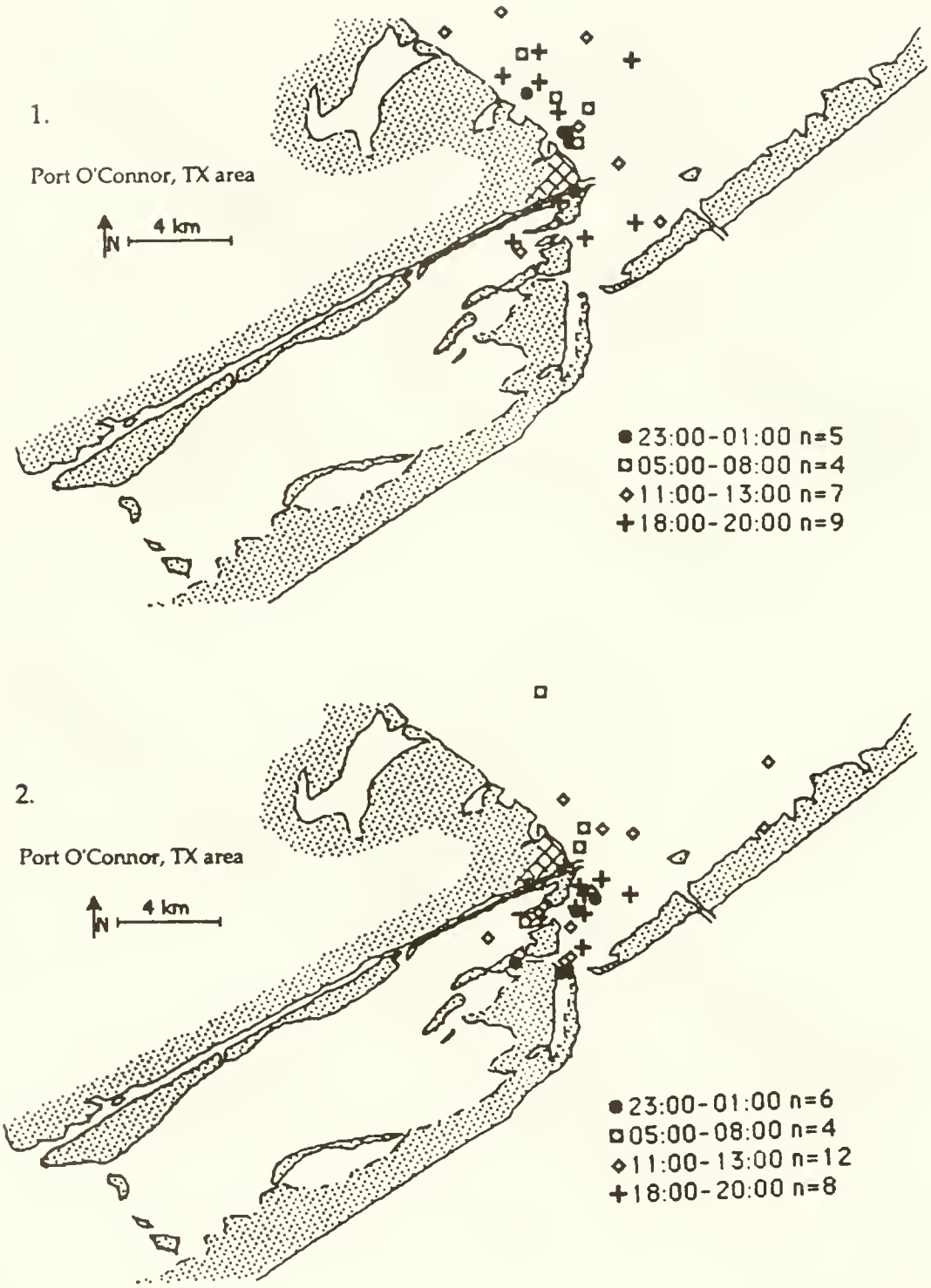




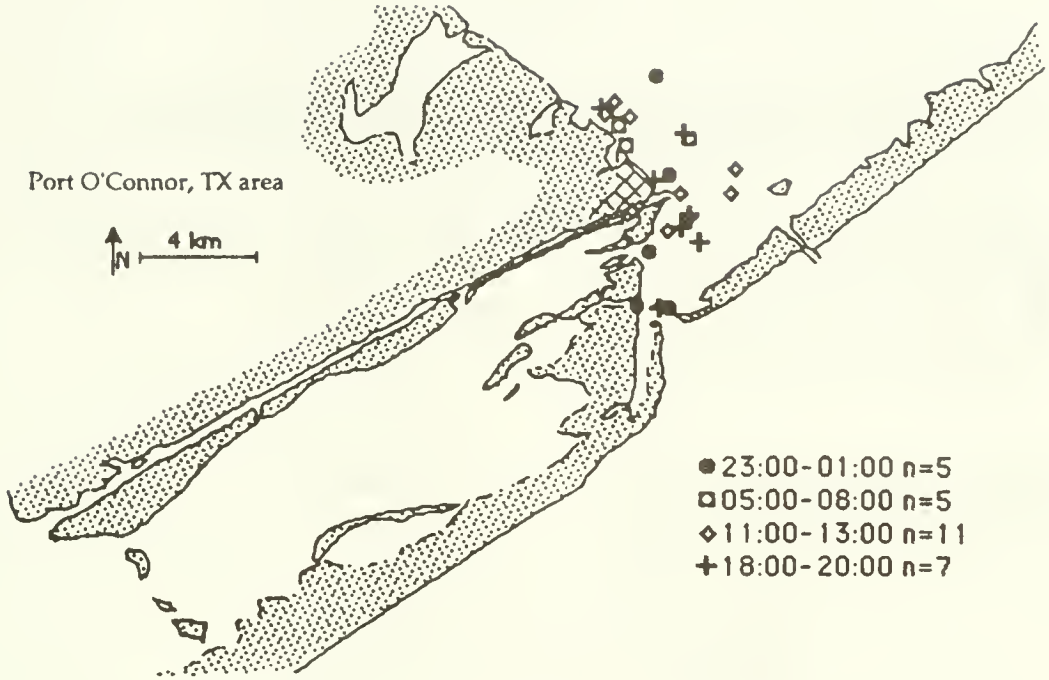
Appendix 5b. Positions of FB504 (1) and FB505 (2) by time of day over the radio-tracking period, from radio-telemetry and sightings.



Appendix 5c. Positions of FB514 (1) and FB515 (2) (captured together) by time of day over the radio-tracking period, from radio-telemetry and sightings.



Appendix 5d. Positions of FB511 (1) and FB522 (2) by time of day over the radio-tracking period, from radio-telemetry and sightings.



Appendix 5e. Positions of FB521 (captured with FB518) by time of day over the radio-tracking period, from radio-telemetry and sightings.

APPENDIX 6

SUMMARY OF OBSERVATIONS ON BIOPSY WOUNDS

Dolphin	Date	Days elapsed	Observations (length by height, mm)
1. FB502 (RT1)	9 Jul 92	0	Captured and biopsied. VHE[a] = B.
	19 Dec 92	163	Small darkly pigmented spot. By contrast, radio bolt holes are darker.
2. FB503	10 Jul 92	0	Captured and biopsied. Pregnant (1st trimester), lactating mother. VHE = B.
	20 Mar 93	253	Not noticeable.
	14 Jul 93	369	Not noticeable.
3. FB505 (RT4)	11 Jul 92	0	Captured and biopsied. Pregnant (1st trimester). VHE = A.
	21 Mar 93	253	Small, lighter spot (21.4 x 14.2). By contrast, radio bolt holes are darker.
4. FB507	11 Jul 92	0	Captured and biopsied. Pregnant (1st trimester). Mother of FB509. VHE = A.
	20 Dec 92	162	Not noticeable (poor photo).
	20 Mar 93	252	Small darker spot (15.1 x 5.0)
5. FB509	11 Jul 92	0	Captured and biopsied. Calf of FB507. VHE = B. Fresh wound appears oval and pink, several mm deep. No other discoloration.

[a] Veterinarian Health Evaluation: A = "no health concerns", B = "would benefit from repeat evaluation", C = "would benefit from therapeutic intervention", D = "serious health concerns" (Sweeney 1992).

Appendix 6, continued.

Dolphin	Date	Days elapsed	Observations (length by height, mm)
	20 Mar 93	252	Not noticeable.
6. FB511 (RT5)	12 Jul 92	0	Captured and biopsied. Pregnant (1st trimester), lactating mother. VHE = A.
	23 Jul 92	11	White to pinkish oval (20.5 x 9.8) with band of darker than normal skin (3.3 mm wide) at edges of wound.
	21 Dec 92	162	Normally pigmented scar tissue (?) or not noticeable.
7. FB514 (RT7)	14 Jul 92	0	Captured and biopsied. VHE = B.
	24 Oct 92	102	No sign of biopsy. By contrast, radio bolt holes appear as small dark spots surrounded by lighter halo where stainless steel washers/magnesium nuts were.
	20 Dec 92	159	As above.
	16 Jun 93	337	As above.
8. FB515 (RT6)	14 Jul 92	0	Captured and biopsied. Mother of FB517. Lactating. VHE = A.
	6 Aug 92	23	Pale gray halo (3.9 mm wide) surrounding white oval (16.2 x 13.2) with darker spot in center (3.6 mm diameter). No other discoloration.
	12 Jan 93	112	Appears to be spot of pigmented scar tissue. By contrast, radio bolt

Appendix 6, continued.

Dolphin	Date	Days elapsed	Observations (length by height, mm)
			holes are very dark spots with whiter halo fading into normal skin.
9. FB516	14 Jul 92	0	Captured and biopsied. VHE = A.
	12 Jan 93	182	No sign of biopsy.
10. FB517	14 Jul 92	0	Captured and biopsied. Calf of FB515. VHE = C.
	13 Sep 92	61	Collected freshly dead (TMMSN ID# PO249). Died of intestinal infarction unrelated to capture (TMMSN 1992). Shallow, diamond shaped indentation, measuring 21x12 mm, normal pigmentation (TMMSN 1992)
11. FB518 (RT8)	15 Jul 92	0	Captured and biopsied. VHE = A.
	26 Aug 92	42	Small white spot (17.5 x 9.4).
12. FB520	15 Jul 92	0	Captured and biopsied. Calf of FB521. VHE = A. Fresh wound appears as deeply pink, oval (29.6 x 15.8) , several mm deep. No other discoloration.
13. FB521 (RT9)	15 Jul 92	0	Captured and biopsied. Mother of FB520. Pregnant (1st trimester), lactating. VHE = B.
	23 Jul 92	8	Oval wound (22.5 x 12.2), white to pinkish with darker spot (4.0 mm diameter) in center. Skin at edge

Appendix 6, continued.

Dolphin	Date	Days elapsed	Observations (length by height, mm)
			(2.7 mm wide band) darker on ventral portion.
	30 Jul 92	15	White spot (poor photo).
	24 Aug 92	40	White spot fading into normal skin. No other discoloration, no apparent indentation.
	24 Oct 92	101	Lighter gray spot (29.0 x 13.3). Shallow indentation?
14. FB522 (RT10)	17 Jul 92	0	Captured and biopsied. VHE = A.
	4 Aug 92	18	Diamond shaped white to pinkish wound (37.2 x 22.1). Darker pinkish horizontal band (12.1 x 5.6) in center. Along dorsal edge, skin at edge of wound (3.2 mm band width) is slightly darker than normal nearby skin otherwise a lighter gray halo fading into normal skin.
15. FB534	19 Jul 92	0	Captured and biopsied. VHE = B.
	1 Aug 92	13	Oval wound with white edges, darker (pinkish) at center (poor photo).
16. FB536	19 Jul 92	0	Captured and biopsied. VHE = A.
	14 Aug 92	26	White oval (32.7 x 18.6).
	7 Jul 93	353	Darkly pigmented oval spot (14.4 x 8.5).
17. FB538	19 Jul 92	0	Captured and biopsied. VHE = A.

Appendix 6, continued.

Dolphin	Date	Days elapsed	Observations (length by height, mm)
	13 Jul 93	359	Normally pigmented spot (31.1 x 13.5) with lighter oval outline. By contrast, rototag hole has left a small, very dark spot with paler halo fading into normal skin.
	7 Nov 93	476	As above (10.5 x 6.2). Diamond shaped outline of paler skin. Comments re rototag as above.